Saarland University

Institute of Sports and Preventive Medicine

Injury Prevention in (Youth) Football (Soccer)

by

Rilind Obërtinca

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This thesis is presented for the award of a Doctor of Philosophy (Sports Medicine) from the Medical Faculty, Saarland University, Saarbrücken, Germany

Declaration

I, Rilind Obërtinca, declare that this thesis, is submitted in partial fulfillment of the requirements for the award of Doctor of Philosophy at the Institute of Sport and Preventive Medicine, of the Medical Faculty of Saarland University, and is wholly my own work unless otherwise referenced or acknowledged. As such, certify to the best of my knowledge and belief that this thesis does not:

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Saarbrücken, 03.10.2024

Obërtinca

Rilind Obërtinca

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Abbreviations

ACL	Anterior cruciate ligament
BMI	Body mass index
CI	Confidence interval
cm	Centimeter
CON	Control
CONSORT	Consolidated Standards of Reporting Trials
DFB	German Football Association
ESM	Electronic Supplementary Material
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
H	Hours
i.e.	Id est
I^2	I square
INT	Intervention
IPP	Injury Prevention Programme
IR	Incidence rate
IRR	Incidence rate ratio
kg	Kilogram
m	Meter
n	Number
NA	Not applicable
OA	Osteoarthritis
p	p value
PEP	Prevent injury and Enhance Performance
PI	Prediction interval
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
RCT	Randomised Controlled Trial
RR	Risk ratio
SD	Standard deviation
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

STROBE-SIIS	STROBE Extension for Sport Injury and Illness Surveillance
T_2	Tau square

List of publications relevant to this thesis

In chronological order:

1. **Obërtinca, R.**, Hoxha, I., Meha, R., Lama, A., Bimbashi, A., Kuqi, D., Shabani, B., Meyer, T., & der Fünten, K. A. (2023). Efficacy of Multi-Component Exercise-Based Injury Prevention Programs on Injury Risk Among Footballers of All Age Groups: A Systematic Review and Meta-analysis. *Sports medicine* (Auckland, N.Z.), 53(4), 837–848. https://doi.org/10.1007/s40279-022-01797-7.

2. **Obërtinca, R.**, Meha, R., Hoxha, I., Shabani, B., Meyer, T., & Aus der Fünten, K. (2024). Efficacy of a new injury prevention programme (FUNBALL) in young male football (soccer) players: a cluster-randomised controlled trial. *British journal of sports medicine*, 58(10), 548– 555. https://doi.org/10.1136/bjsports-2023-107388

3. **Obërtinca, R.**, Meyer, T., & Aus der Fünten, K. (2024). Epidemiology of football-related injuries in young male football players. An additional analysis of data from a cluster-randomised controlled trial. *Science & medicine in football*, 1–11. Advance online publication. https://doi.org/10.1080/24733938.2024.2369545

Abstract

Introduction: Playing football carries a significant risk of injury. Since injuries can negatively affect both health and performance, injury prevention is a priority. Aiming to reduce the number of football injuries, various multi-component exercise-based prevention programmes (IPPs) (e.g. FIFA® 11, FIFA® 11+, 11+ Kids, Prevent Injury and Enhance Performance (PEP), and HarmoKnee) were established and examined in studies. These studies focused either on children up to the age of 12 years or on 'adults'. However, after the age of 14, no further distinctions were made, and players were generally grouped with adults. In the cluster RCTs where efficacy was investigated, the results were promising. A major challenge of all IPPs is their implementation and subsequent adherence in the field. The main intentions of this thesis were two-fold: firstly, to provide a detailed analysis of the efficacy of existing programmes, and secondly, to develop and evaluate a new IPP targeting a previously underrepresented group, youth players aged 13-19 years. This age group is distinct from both children and adults. It is crucial to address this age group separately, given their unique physical, developmental, and performance demands. Furthermore, the intention of the new programme was to increase its attractiveness and its wake the adherence to it. This cumulative thesis consists of three publications.

Methods: A systematic review and meta-analysis of randomised and cluster-randomised controlled trials was conducted to investigate the efficacy of multi-component exercise-based IPPs on the overall number of injuries, body region-specific injuries, contact, and non-contact injuries.

ii) The 'FUNBALL' programme was developed, and its efficacy was investigated through a two-armed cluster-randomised controlled trial (cluster-RCT). 55 teams were randomly assigned to the intervention group (INT; 28 teams) and the control group (CON; 27 teams). The INT group performed the 'FUNBALL' programme after their usual warm-up at least twice per week. The CON group followed their usual training routine. The outcomes included the overall number of football-related injuries, region-specific injuries of the lower limbs (hip/groin, thigh, knee, lower leg, ankle, and foot), and injury severity. Study iii) entailed a detailed secondary analysis of the aforementioned study, and investigated the injuries within the control group.

Results: i) Fifteen randomised and cluster-RCTs met the inclusion criteria and were incorporated into the analysis. Results from this study suggested uncertainty and inconclusiveness regarding the efficacy of multi-component exercise-based injury prevention programmes in football. The calculation of prediction intervals (PIs) resulted in a wide range of efficacy, varying from very protective to an increased risk of injury. ii) The 'FUNBALL' programme reduced the incidence of football-related injuries among male adolescent football players. Specifically, reduced the incidence of overall injuries (incidence rate ratio (IRR) 0.69), of thigh injuries (IRR 0.62), of moderate (time loss between 7 and 28 days) (IRR 0.65) and of severe injuries (time loss >28 days) (IRR 0.51). iii) The study's findings suggest a lower injury incidence in youth players compared to adults. Additionally, a higher injury incidence was observed in older age groups.

Discussion: In contrast to several meta-analyses conducted previously to investigate the efficacy of multi-component exercise-based IPPs, the first study incorporated prediction intervals (PIs) into the analysis. The findings revealed a need for more cautious interpretation of their efficacy. The 'FUNBALL' programme emerged as an effective intervention that reduced injury incidence in youth football players. However, further investigation to determine whether this specificity enhances adherence compared to previous programs. The third study revealed a lower injury incidence in youth players compared to adults whereas injury locations were similar. The thigh, knee, and ankle were the most commonly injured body regions. Finally, the increase in injury incidence among older age groups can assist medical staff and coaches in anticipating injury types and locations.

Chapter 1: Introduction and Literature Review

1.1. Football-related injuries in football with the focus on youth male players

Injuries in football represent a real concern. The injury incidence differs when analyzed by level of participation (amateur and professional), age groups (children, youth, adults, and veterans), and sex (male and female). In male football, professional players exhibit a higher overall injury incidence rate (IR) compared to youth players (8.1 vs. 5.7 injuries/1000 football hours) (López-Valenciano et al., 2020; Robles-Palazón et al., 2022). Data on children (under 12 years) and veterans are less available. Rössler et al. (2016) reported an injury IR of 1.1 injuries/1000 football hours, whereas Hammes et al. (2015) reported an IR of 12.4 injuries/1000 football hours in German veteran players. Taking into account the different stages of development from childhood to adulthood, differences are also observed in the types and locations of injuries. In youth football, the negative effects of injuries in several domains have been previously documented. Mainly, the research has focused on the impact of injuries in health (Koch et al., 2021) and in performance (Hägglund et al., 2013; Larruskain et al., 2021).

1.2. Impact of injuries on youth footballers' health

Musculoskeletal injuries, such as muscle strains and ligament sprains, are most prevalent in youth football (Robles-Palazón et al., 2022). These injuries not only result in immediate pain and disability but also carry the potential for long-term health consequences, such as chronic pain and joint instability. Knee injuries, including meniscus tears, are identified as potential risk factors for knee osteoarthritis (OA). According to Koch et al. (2021), football-related injuries contribute to the premature end of professional football careers, with knee and ankle injuries emerging as most common sites associated with sports induced retirements. Another significant concern lies in the adverse effects of concussions, which lead to notable declines in cognitive functions, such as memory, psychomotor skills, executive function, and self-reported cognitive abilities (Cunningham et al., 2020). Finally, injuries also pose considerable psychological challenges, including heightened levels of anger, depression, anxiety, tension, fear, and diminished self-esteem (Walker et al., 2007).

1.3. Impact of injuries on youth footballers' performance

The negative impact on performance resulting from football-related injuries is a significant concern. It has implications for both, players individually and their teams. Injuries can disrupt training routines, limit physical conditioning, and hinder skill development, all of which are necessary for optimal performance on the field. Recently, is reported that injuries have a negative impact on player progression in elite youth players (Larruskain et al., 2021). Athletes recovering from injuries often experience a decline in physical abilities such as speed, agility, and strength, which are crucial for competitive play (Kraemer et al., 2009). Hagglund et al. (2013) reported that teams with lower injury rates and severity compared to the preceding season statistically had a better chance of improved team performance. Moreover, teams with lower injury incidence showed a strong correlation with higher league positions, more games won, more goals scored, and greater goal difference and total points (Eirale et al., 2013).

1.4. Aims of the PhD-Thesis

This thesis includes several chapters. Each addresses a specific research question concerning football-related injuries and their prevention. Each of these topics was explored with the intention of addressing the overall research aims. Those were established based on a literature review and on-field opinions regarding injury prevention in football. This topic remains of high importance for both the scientific staff and practitioners, considering the high incidence of injuries reported in youth football. Initially, a review of the existing literature revealed that no meta-analyses have used the 'strongly recommended' PIs in their analyses. Additionally, although a few studies in youth football have investigated the efficacy of IPPs designed for adult footballers, there is a lack of IPPs specifically targeting youth footballers. Furthermore, the challenges of maintaining long-term adherence to existing IPPs are well-documented. Therefore, the following research aims were established:

Study 1. To investigate the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups in comparison to a control group.

Study 2. To evaluate the efficacy of a new multi-component, exercise-based injury prevention programme 'FUNBALL' in 13-19 years old male football players.

Study 3. To investigate the epidemiology of football-related injuries in 13-19 years old male players.

1.5. Literature review

The following section includes the submitted manuscript related to the following publication:

Obërtinca, R., Hoxha, I., Meha, R., Lama, A., Bimbashi, A., Kuqi, D., Shabani, B., Meyer, T., & der Fünten, K. A. (2023). Efficacy of Multi-Component Exercise-Based Injury Prevention Programs on Injury Risk Among Footballers of All Age Groups: A Systematic Review and Meta-analysis. *Sports medicine* (Auckland, N.Z.), 53(4), 837–848.

The citations and references in this section pertain solely to this manuscript and are formatted according to the requirements of *Sports Medicine*. The numerical citations refer exclusively to the reference list within this section and do not correspond to the reference list at the end of the thesis.

Title:

Efficacy of multi-component exercise-based injury prevention programs on injury risk among footballers of all age groups: A systematic review and meta-analysis

Authors:

Rilind Obërtinca,[1,3] Ilir Hoxha,[2,4,5] Rina Meha,[1, 4] Arber Lama,[4,5,6] Altina Bimbashi,[4] Dorentina Kuqi,[4] Bujar Shabani,[4,6] Tim Meyer,[1] Karen aus der Fünten[1]

Author affiliations:

1. Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany.
2. Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, New Hampshire, United States.
3. Department of Physiotherapy, University of Gjakova "Fehmi Agani", Gjakova, Kosovo.
4. Research Unit, Heimerer College, Prishtina, Kosovo.
5. Evidence Synthesis Group, Prishtina, Kosovo.
6. University Clinical Center of Kosovo, Prishtina, Kosovo.

Correspondence to:

Rilind Obërtinca
e-mail: riob00001@stud.uni-saarland.de

Saarland University
Institute of Sports and Preventive Medicine
Campus, Building B8 2
66123 Saarbrücken
Germany

Abstract

Background: Playing football is associated with a high risk of injury. Injury prevention is a priority as injuries do not only negatively impact health but also potentially performance. Various multi-component exercise-based injury prevention programs for football players have been examined in studies.

Objective: To investigate the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups in comparison to a control group.

Methods: We conducted a systematic review and meta-analysis of randomized and cluster-randomized controlled trials. CINAHL, Cochrane, PubMed, Scopus and Web of Science databases were searched from inception to June 2022. The following inclusion criteria were used for studies to determine their eligibility: they (1) include football (soccer) players, (2) investigate the preventive effect of multi-component exercise-based injury prevention programs in football, (3) contain original data from a randomized or a cluster-randomized trial, and (4) investigate football injuries as the outcome. The risk of bias and quality of evidence were assessed using the Cochrane Risk of Bias Tool and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE), respectively. The outcome measures were the risk ratio (RR) between the intervention and the control group regarding the overall number of injuries, body region-specific, contact and non-contact injuries sustained during the study period in training and match play.

Results: Fifteen randomized and cluster-randomized controlled trials with 22,177 players, 5080 injuries, and 1,587,327 exposure hours, fulfilled the inclusion criteria and reported the required outcome measures. The point estimate (RR) for the overall number of injuries was 0.71 (95% confidence interval, 0.59 to 0.85; 95% prediction interval, 0.38 to 1.32) with very low-quality evidence. The point estimate (RR) for lower limb injuries was 0.82 (95%CI, 0.71 to 0.94; 95%PI, 0.58 to 1.15) with moderate-quality evidence; for hip/groin injuries, the RR was 0.56 (95%CI, 0.30 to 1.05; 95%PI, 0.00 to 102.92) with low-quality evidence; for knee injuries, the RR was 0.69 (95%CI, 0.52 to 0.90; 95%PI, 0.31 to 1.50) with low-quality evidence; for ankle injuries, the RR was 0.73 (95%CI, 0.55 to 0.96; 95%PI, 0.36 to 1.46) with moderate-quality evidence; and for hamstring injuries, the RR was 0.83 (95%CI, 0.50 to 1.37) with low-quality evidence. The point estimate (RR) for the contact injuries was 0.70 (95%CI, 0.56 to 0.88; 95%PI, 0.40 to 1.24) with moderate-quality evidence, while for non-contact injuries, the RR was 0.78 (95%CI, 0.55 to 1.10; 95%PI, 0.25 to 2.47) with low-quality evidence. 133486

Conclusion: This systematic review and meta-analysis indicated that the treatment effect associated with the use of multi-component exercise-based injury prevention programs in football is uncertain and inconclusive. In addition, the majority of the results is based on low-quality of evidence. Therefore, future high-quality trials are needed to provide more reliable evidence.

Registration number: PROSPERO CRD42020221772

Key Points

- The present meta-analysis is the first to use prediction intervals (PIs) in the interpretation of results derived from trials assessing the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups.
- This study revealed that evidence for meaningful effects of exercise-based injury prevention programs remains inconclusive at best.
- The quality of evidence is a major issue in existing studies, therefore, these findings call for future high-quality trials to provide more reliable evidence.

1 Background

The overall injury incidence in professional male football players is between 5.9 [1] and 9.6 [2] injuries/1000 football hours. In amateur and veteran football reported incidences are even higher and reach 9.6 [2] to 12.5 [3] and 12.4 [4] injuries/1000 football hours, respectively. There are hardly any data regarding players under the age of 11 years [5]. A professional football team with 25 players suffers approximately 50 injuries per season [6], and youth elite teams about 30 [7]. Many efforts have been made in recent years to reduce these numbers. Various injury prevention programs for football players of both sexes and various age groups have been established. Some of them target specific injuries, for example, Prevent injury and Enhance Performance [8], HarmoKnee [9] target knee injuries. Others take a more general approach, trying to prevent non-contact lower extremity injuries in general for example, FIFA ® 11 [10], FIFA® 11+ [11], and the

Neuromuscular training program [12]. 11+ Kids [13] aims to prevent football injuries by increasing children's fundamental and sport-specific motor skills.

Previous systematic reviews and meta-analyses have evaluated the efficacy of either specific programs (e.g., FIFA 11 and 11+) [14, 15] or the effect of various programs on specific injuries (e.g., non-contact injuries) [16]. However, recognising the differences between programs regarding the content, the different age groups targeted, and the different results reported compared to each other, a comprehensive meta-analysis of pooled results across the studies will produce a more comprehensive result. Up to date, no meta-analysis is available which has evaluated the efficacy of all multi-component exercise-based injury prevention programs in reducing the overall number of injuries as well as body region-specific injuries, and considering footballers of all age groups (children, youth, senior, and veteran). Additionally, contact-related injuries represent 50% of overall injuries in professional football [17]. Previous research has not investigated the impact of the programs on preventing these injuries. Providing information about the age-specific efficacy and estimating the potential of these programs on contact-related injuries may guide future evidence-based directions regarding the implementation and development of new interventions. Finally, providing only confidence intervals (CIs) might not be the best way forward. A recent meta-analysis examined the effect of the Nordic hamstring exercise [18]. The authors strongly recommended providing the prediction intervals (PIs) in addition to confidence intervals. This is in line with authors promoting the use of PIs in the interpretation of results from a random-effects meta-analysis in trials assessing treatment effects [19]. Therefore, and for the first time, this meta-analysis reports the PIs in addition to the CIs. The aim of this meta-analysis was to investigate the efficacy of multi-component exercise-based injury prevention programs in reducing injuries of different types among footballers of all age groups.

2 Methods

2.1 Protocol and registration

We report this systematic review in accordance with the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) checklist for network meta-analyses [20]. The study was registered at PROSPERO (ID: CRD42020221772).

2.2 Study eligibility criteria

In the present study, we included all controlled, multi-component exercise-based injury prevention programs containing at least two or more exercises. Players of the intervention group performed these programs during their training sessions in addition to their usual training and were compared to a control group. Criteria for study inclusion were: (1) include football (soccer) players, (2) investigate the preventive effect of multi-component exercise-based injury prevention programs in football, (3) contain original data from a randomized or a cluster-randomized trial, and (4) investigate football injuries as the outcome. Studies were excluded from the meta-analysis if they were: (1) studies with single exercise intervention, (2) studies with a primary target on performance or other physical measurements than injuries, (3) studies using protective equipment (e.g., bracing) as part of the intervention, and (4) studies published in a language other than English.

2.3 Sources and study selection

Possible studies were identified by using a systematic search process. First, we searched the following databases CINAHL, Cochrane, PubMed, Scopus, and Web of Science from the earliest record to June 2022, with the following search strategy: (injury prevention OR warm-up program OR neuromuscular program OR f-marc OR 11+) AND (football OR soccer). The reference lists of the studies recovered were hand searched to identify potentially eligible studies missed by electronic searches. Two reviewers independently (AB, DK) performed the selection of studies based on the title and abstract provided by the bibliographic databases. The full-text evaluation followed on those selected studies from the first selection step. A third reviewer (RO) was responsible for resolving any discrepancies in the selection process.

2.4 Data extraction and administration

For each eligible study, four reviewers (RM, AB, DK, AL) extracted data independently using a standardized data extraction form [14]. One section was added (type of injuries: contact or non-contact) to the extraction form for additional analysis which we performed, regarding the effect on contact versus non-contact injuries. We extracted data on the studies' basic information, design, participants, intervention characteristics, and outcome measures. Thereafter, the reviewers compared the extracted data for consistency. Reviewers resolved discrepancies by discussion and, when necessary, a fifth party (RO) was involved. Final decisions were made based on a majority vote. Primary outcome results from individual studies were extracted and collated in Excel 365 (Microsoft Corp).

2.5 Quality assessment

The risk of bias was assessed for each included trial according to the recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions [21]. The following items were considered: allocation sequence generation, concealment of allocation, blinding outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. As it is impossible to blind the participants to the intervention, we removed the item “blinding of participants and investigators”. Each bias domain was judged as low or high risk of bias according to its possible effect on the results of the study. When the possible effect was unknown or insufficient detail was reported, we judged it as unclear. The risk of bias was examined independently by two reviewers (RO, BSH). Discrepancies were resolved by consensus. The overall quality of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE). This approach is a method for assessing the strength of evidence derived from systematic reviews [22]. In the GRADE system, RCTs begin as high-quality evidence [23]. Subsequently, the evidence was downgraded by one level for each of the following domains considered: (1) risk of bias (downgraded by one level if the trials scored an overall high risk of bias on the Cochrane Collaboration Risk of Bias Tool); (2) inconsistency (downgraded by one level if statistical heterogeneity between studies was $I2 > 50\%$); (3) indirectness (downgraded by one level if meta-analysis included participants with heterogeneous characteristics with regard to sex, age, and level of sport); (4) imprecision (downgraded by one level if the upper and lower CIs had > 0.5 difference) and (5) publication bias (assessed with a visual inspection of funnel plot and two-tailed Egger test if >10 studies were included in the meta-analysis). Evidence obtained was categorised into four levels of evidence quality: high, moderate, low, and very low [24] (Table 1).

Table 1 Grades of recommendation, assessment, development and evaluation (GRADE) quality of evidence

Meta-analyses	Number of RCT's	Risk of bias[a]	Inconsistency[b]	Indirectness[c]	Imprecision[d]	Publication bias[e]	Effect RR (95% CI)	GRADE quality
Overall injuries All studies	11	○	○	⊕	⊕	○	0.71 (0.59 to 0.85)	⊕⊕○○○ Very low
Lower limb injuries All studies	9	○	⊕	⊕	⊕	-	0.82 (0.71 to 0.94)	⊕⊕⊕○ Moderate
Hip/groin injuries All studies	3	○	⊕	⊕	○	-	0.56 (0.30 to 1.05)	⊕⊕○○ Low
Hamstring injuries All studies	2	○	⊕	⊕	○	-	0.83 (0.50 to 1.37)	⊕⊕○○ Low
Knee injuries All studies	11	○	○	⊕	⊕	⊕	0.69 (0.52 to 0.90)	⊕⊕⊕○○ Low
Ankle injuries All studies	7	○	⊕	⊕	⊕	-	0.73 (0.55 to 0.96)	⊕⊕⊕○ Moderate
Contact injuries All studies	6	○	⊕	⊕	⊕	-	0.68 (0.55 to 0.84)	⊕⊕⊕○ Moderate
Non-Contact injuries All studies	6	○	○	⊕	⊕	-	0.73 (0.53 to 1.01)	⊕⊕○○ Low

[a] Downgraded if the trials scored an overall high risk of bias on the Cochrane Collaboration Risk of Bias Tool.

[b] Downgraded if statistical heterogeneity between studies was ($I^2 > 50\%$).

[c] Downgraded by one level if meta-analysis included participants with heterogeneous characteristics.

[d] Downgraded if the upper and lower CIs had >0.5 difference.

[e] Assessed with visual inspection of the funnel plot and two-tailed Egger test (if >10 studies were included in the meta-analysis).

2.6 Outcome measures

The primary outcome was the risk ratio (RR) regarding the overall number of injuries. Lower limb injury and region-specific injury risk ratios (RRs) for the hamstring, hip/groin, knee, and ankle regions were secondary outcomes. Additionally, the overall number and the region-specific injury RRs were assessed for a non-contact versus contact-induced cause. All injuries occurring in official training and match play during the respective study period were included.

2.7 Synthesis of results

If studies did not report risk ratio estimates, we converted them to risk ratios as far as possible [25, 26]. Out of the 15 included studies, six studies did not perform cluster adjustments. They also did not provide information on the intra-cluster correlation coefficient or other data that would allow for calculating the design effect or inflation factor (as recommended by the Cochrane Handbook for Systematic Review of Interventions) [27]. Hence, we performed a cluster adjustment by increasing variance by 30% for effect estimates of studies with no adjustment for the cluster effect [28]. We performed a meta-analysis of risk ratios (RR) and their 95% confidence intervals using the DerSimonian and Laird random-effects method [29]. Random-effects meta-analysis assumes that the true treatment effect varies among studies. The DerSimonian and Laird method does not make any assumptions about the distribution of the random effects [30]. In addition to the presentation of overall effect estimates and 95% confidence intervals, we also calculated 95% prediction intervals. They enable examination of treatment effects within an individual study setting, as this can differ from the average effect [19]. Heterogeneity was assessed using I^2, τ^2, and Q value (χ^2 test for heterogeneity). We interpreted I^2 values according to Higgins et al.'s guidelines, a low heterogeneity for I^2 values between 25%–50%, a moderate for 50%–75%, and a high for ≥75% [27]. A small study effect was investigated using Egger's test for meta-analysis with 10 or more studies [31]. Statistical analysis was carried out using STATA 17 BE (Stata Corp).

3 Results

3.1 Literature identification

The initial database search identified 7954 studies. Following the removal of duplicates (n=4986) 2968 studies remained. After screening the titles and abstracts 69 full-text articles were left. A further 54 studies had to be excluded as they did not present data on injuries, included non-football players, or were neither Cluster RCTs nor RCTs. Finally, 15 articles were included in the meta-analysis (Fig. 1).

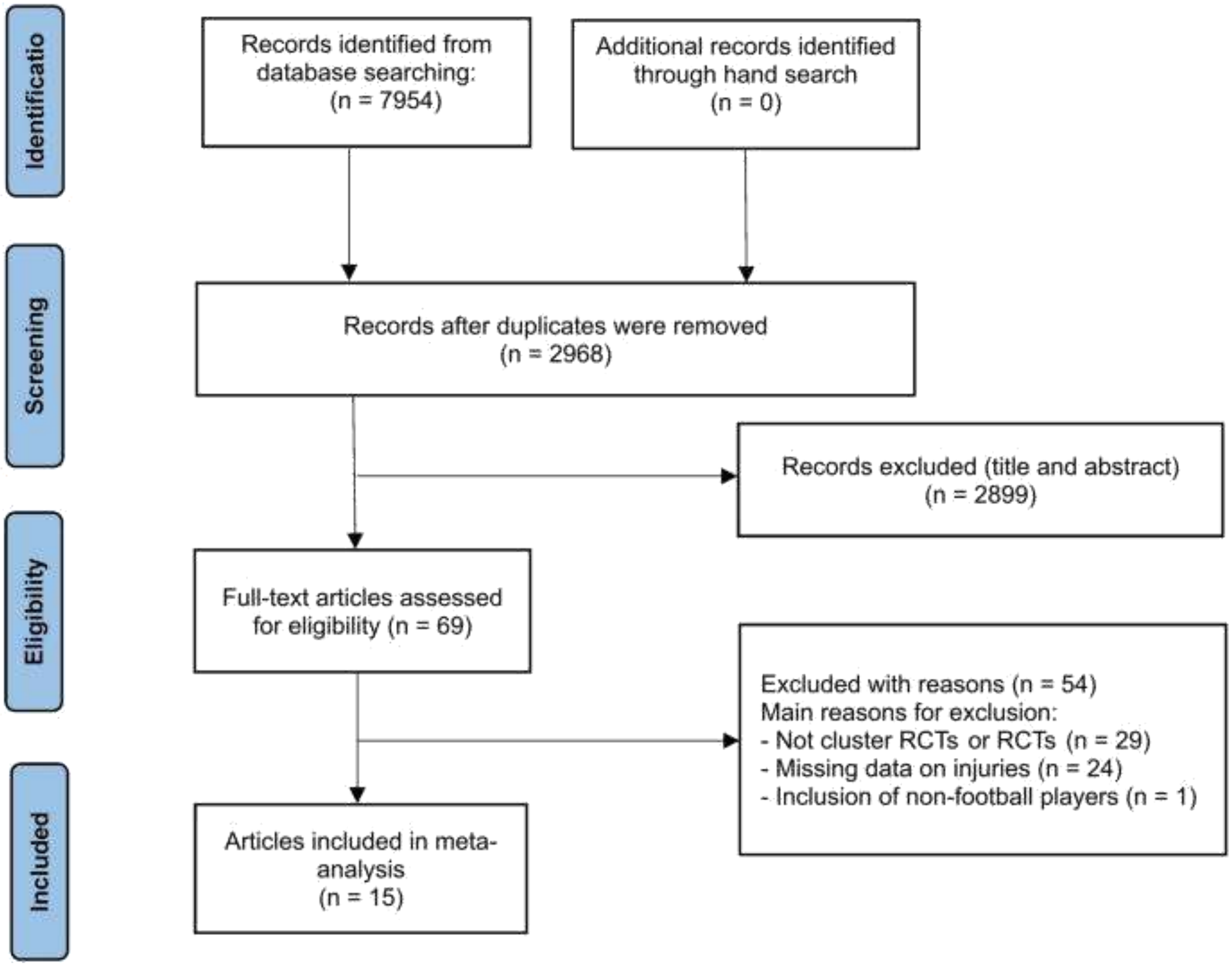

Fig. 1 Flow chart of the included studies. RCTs randomized controlled trials

3.2 Demographic and study characteristics

Eight trials stemmed from Europe [4, 9, 10, 11, 13, 32, 33, 34]. Two trials were conducted in the USA [8, 35]. One trial was conducted in one each of the following countries: Canada [12], Australia [36], Rwanda [37], Nigeria [38], and Iran [39]. The overall number of participants was 23,177 including both sexes. Participants were registered football players in one of the following age groups: children (7-14 years), youth (12-19 years), senior, and veteran (>32 years). The number of participants ranged from 265 [4] to 4564 participants [9]. A total of 5080 injuries and 1,587,327 hours of exposure is included. The study period lasted between 12 weeks [8] and 9 months [4, 13, 33, 39]. All interventions were applied at least twice a week in the training sessions. The control groups performed their usual warm-up exercises and/or training routines. One study required an additional home-based stretching program [12]. Nine studies used a FIFA® warm-up program either the FIFA® 11, the FIFA® 11+, or the 11+ Kids [4, 10, 11, 13, 33, 35, 37, 38, 39]. Two studies used Neuromuscular Training programs [12, 32], and one study for each the neuromuscular control program [36], the Knäkontroll program [9], the Prevention Injury and Enhance Performance program (PEP) [8], and the Bounding Exercise Program [34] (Table 2).

Table 2 Summary of included multicomponent RCT studies investigating the effect of injury prevention programs

Study	Intervention program	Population	Follow-up	Outcome	Number of analysed (players)	Exposure time (hours)	Number of injuries
Emery et al. 2010 [10]	Neuromuscular training program	Male and female youth, (13-18 years)	20 weeks	Overall injuries	IG: 380 CG: 364	IG: 24 051 CG: 24 597	IG: 50 CG: 79
Finch et al. 2016 [9]	Neuromuscular control program	Male senior, (18-30 years)	28 weeks	Overall injuries	IG: 679 CG: 885	IG: 12 790[a] CG: 15 537[a]	IG: 335 CG: 438
Gilchrist et al. 2008 [6]	PEP	Female senior, (19.88 years)[b]	12 weeks	Non-contact ACL injuries	IG: 583 CG: 852	IG: 35 220 CG: 52 919	IG: 40[c] CG: 58[c]
Hammes et al. 2015 [1]	FIFA® 11+	Male veteran, (≥32 years)	9 months	Overall injuries	IG: 146 CG:119	IG: 4 172 CG: 2 937	IG: 51 CG: 37
Hilska et al. 2021 [14]	Neuromuscular training	Male and female children, (9-14 years)	20 weeks	Overall injuries	IG: 673 CG: 730	IG: N/A CG: N/A	IG: 310 CG: 346

Nuhu et al. 2021 [27]	FIFA® 11+	Male senior, (IG: 19.9 years) (CG:19.7 years))	7 months	Overall injuries	IG: 309 CG: 317	IG: 65 333 CG: 63 389	IG: 163 CG: 200
Owoeye et al. 2014 [33]	FIFA® 11+	Male youth, (14–19 years)	6 months	Overall injuries	IG: 212 CG: 204	IG: 51 017 CG: 61 045	IG: 36 CG: 94
Rossler et al. 2018 [12]	11+ Kids	Male and female children, (7-13 years**)**	9 months	Overall injuries	IG: 2066 CG: 1829	IG: 140 716 CG: 152 033	IG: 139 CG: 235
Silvers-Granell et al. 2017 [26]	FIFA® 11+	Male senior, (18–25 years)	5 months	Overall injuries	IG: 675 CG: 850	IG: 35 226 CG: 44 212	IG: 285 CG: 665
Soligard et al. 2008 [11]	FIFA® 11+	Female youth, (13–17 years)	8 months	Overall injuries	IG: 1055 CG: 837	IG: 49 899 CG: 45 428	IG: 161 CG: 215
Steffen et al. 2008 [24]	FIFA® program 11	Female youth, (13–17 years)	8 months	Overall injuries	IG: 1073 CG: 947	IG: 66 423 CG: 65 725	IG: 242 CG: 241
Walden et al. 2012 [7]	Knakontrol	Female youth, (12–17 years)	7 months	ACL injuries	IG: 2479 CG: 2085	IG: 149 214 CG: 129 084	IG: 7[c] CG: 14[c]
Zarei et al. 2020 [13]	11+ kids	Male children, (7-14 years**)**	9 months	Overall injuries	IG: 443 CG: 519	IG: 31 934 CG: 32 113	IG: 30 CG: 60

Van de Beijsterveldt et al. 2012 [16]	FIFA® program 11	Male senior, (18−40 years)	9 months	Overall injuries	IG: 233 CG: 233	IG: 21 605 CG: 22 647	IG: 207 CG: 220
Van de Hoef et al. 2019 [25]	BEP	Male senior, (18-45 years)	39 weeks	Hamstring injuries	IG: 229 CG: 171	IG: 31 831 CG: 21 717	IG: 35[f] CG: 30[f]

ACL anterior cruciate ligament, BEP bounding exercise program, CG control group, IG intervention group, N/A Not applicable, PEP Prevent injury and Enhance Performance

[a] Match exposure only was reported

[b] Average age only was reported

[c] Knee injuries

[d] Lower limb injuries

[e] ACL injuries

[f] Hamstring injuries

3.3 Risk of bias

Seven (46%) studies had a high risk of bias in two or more domains. The domain "other bias" was the most frequent cause for a high risk of bias within the studies (46%), with seven studies neither reporting an intention to treat analysis nor an adjustment for clustering (Fig. 1 and Table 1 of the Electronic Supplementary Material [ESM]).

3.4 Meta-analysis results

3.4.1 Overall, body region, contact and non-contact related injuries

For the primary outcome analysis, i.e., the overall injury risk, the pooled results showed a point estimate (RR) of 0.71 (95%CI, 0.59 to 0.85; 95%PI, 0.38 to 1.32; $I2=80.5\%$; $\tau2= 0.067$; $p<0.001$). The width of the 95% PI suggests that the effect in future similar studies lies between 0.38 and 1.32 (Fig. 2). In practical terms, the effect may vary from being very protective to an increased risk of injury. The level of evidence was rated as very low (downgraded one level due to risk of bias, one level due to inconsistency, and one level due to publication bias) (Table 1).

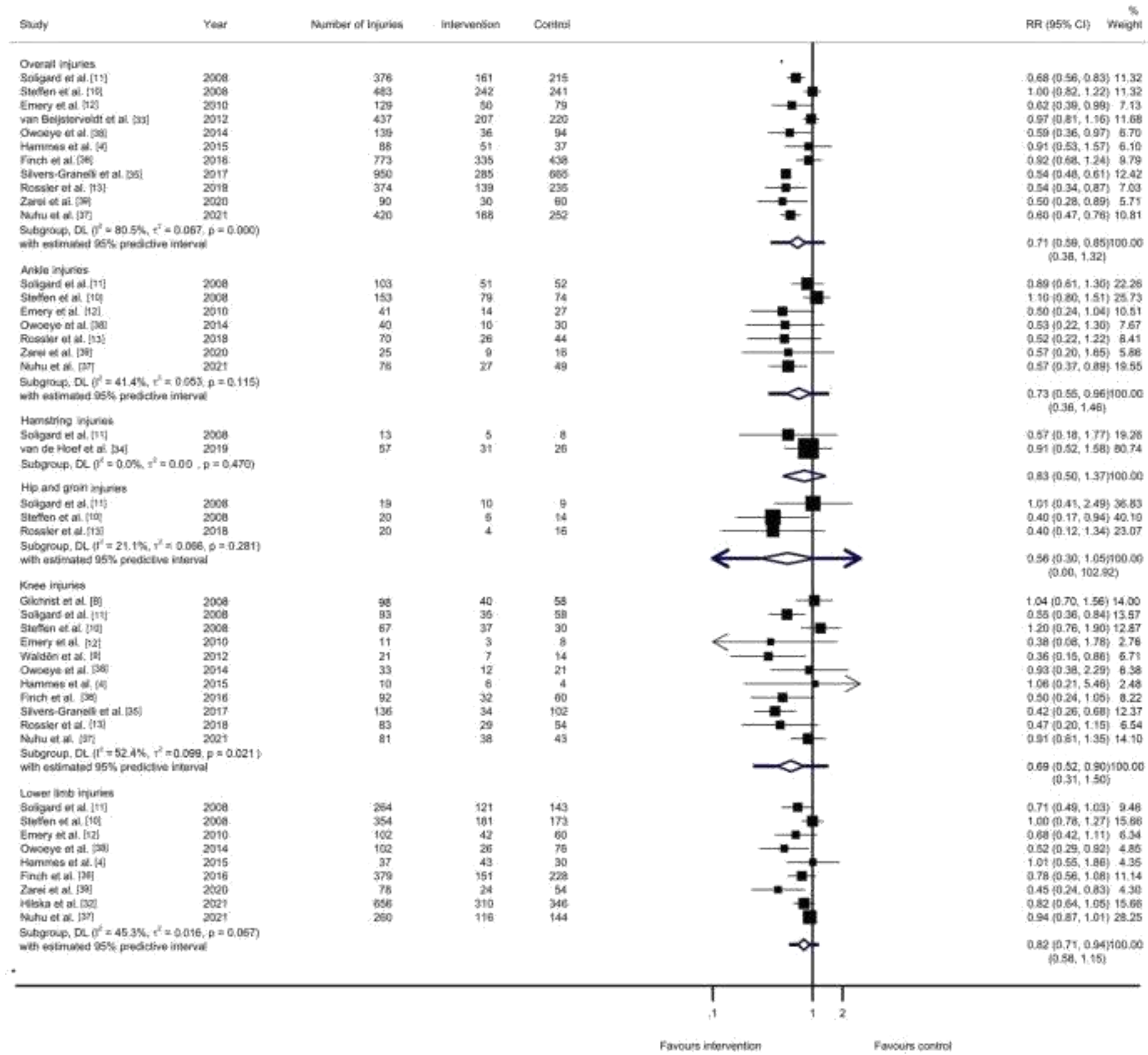

Fig. 2 Analysis of multi-component exercise-based injury prevention programs' effect on the overall and region-specific injury risk compared with control groups.

I^2 I square, p p value, RR risk ratio, τ^2 tau square

Regarding the secondary outcome analyses, i.e., the body region-specific injury risk (Figure 2), the point estimate (RR) for the lower limb injuries was 0.82 (95%CI, 0.71 to 0.94; 95%PI, 0.58 to 1.15; I2=45.3%; τ2=0.016; p=0.067) with moderate-level evidence (downgraded one level due to risk of bias). For the knee injuries, the RR was 0.69 (95%CI, 0.52 to 0.90; 95%PI, 0.31 to 1.50) with low-level evidence (downgraded one level due to risk of bias, one level due to inconsistency, and one level due to publication bias). For the hip/groin injuries, the RR was 0.56 (95%CI, 0.30 to

1.05; 95%PI, 0.00 to 102.92) with low-level evidence (downgraded one level due to risk of bias and one level due to imprecision). For the hamstring injuries, the RR was 0.83 (95%CI, 0.50 to 1.37) with low-level evidence (downgraded one level due to risk of bias and one level due to imprecision). And for the ankle injuries, the RR was 0.73 (95%CI, 0.55 to 0.96; 95%PI, 0.36 to 1.46) with moderate-level evidence (downgraded one level due to risk of bias). For each calculation, the 95% PI resulted wider in comparison to the 95% CI.

The pooled results for non-contact injuries showed a point estimate (RR) of 0.78 (95%CI, 0.55 to 1.10; 95%PI, 0.25 to 2.47; I^2=67.3%; τ^2=0.100; p=0.016), with evidence rated as a low-level (downgraded one level due to risk of bias and one level due to inconsistency). Additionally, the point estimate (RR) for contact injuries was 0.70 (95%CI, 0.56 to 0.88; 95%PI, 0.40 to 1.24 I^2=29.2%; τ^2=0.018; p=0.227), with moderate-level evidence (downgraded one level due to risk of bias). The width of the 95% PI suggested that the effect may vary from being very protective to an increased risk of injury for both outcomes, i.e., non-contact injuries (PI 0.55-1.10) and contact injuries (PI 0.40-1.24) (Fig. 3).

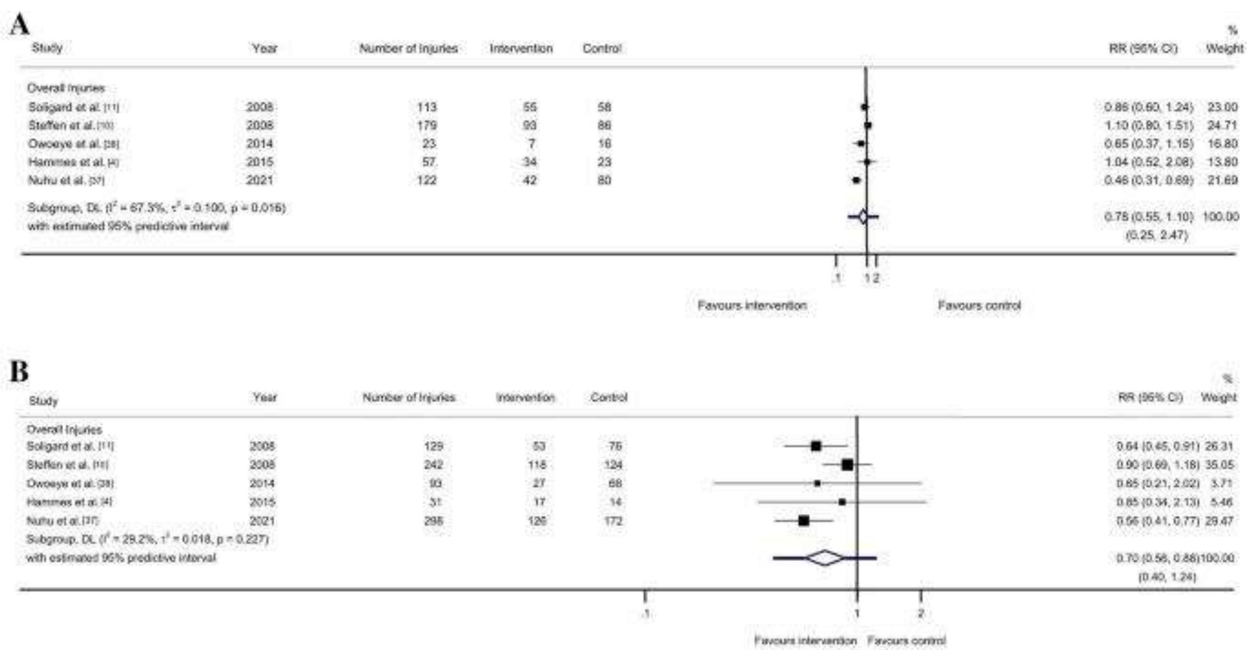

Fig 3. Analysis of multi-component exercise-based injury prevention programs' effect on the overall non-contact (a) and contact (b) injury risk compared with control groups.

I^2 I square, p p value, RR risk ratio, τ^2 tau square

3.4.2 Subgroup analysis according to sex

Regarding a distinction between males and females, the point estimate (RR) for the overall number of injuries in male football players was 0.70 (95%CI, 0.55 to 0.90; I^2=83.5%; τ^2=0.082; p<001). In female football players the point estimate (RR) was 0.82 (95%CI, 0.57 to 1.20; I^2=68.9%; τ^2=0.064; p=0.008) (Fig. 4 of the ESM).

3.4.3 Subgroup analysis according to age group

The point estimate (RR) for the overall number of injuries in children was 0.52 (95%CI, 0.36 to 0.76; I^2=0.0%; τ^2<0.001 p=0.841), in youth the RR was 0.74 (95%CI, 0.56 to 0.97; I^2=68.9%; τ^2=0.048; p=0.022), in seniors 0.73 (95%CI, 0.53 to 1.01; I^2=91.1%; τ^2=0.098; p<0.001), and in veterans 0.91 (95%CI, 0.53 to 1.57) (Fig. 4 of the ESM).

4 Discussion

4.1 Principal findings

This systematic review and meta-analysis included 15 RCTs that assessed the effect of injury prevention programs on the overall and body region-specific injury risk in football players. Based on calculated PIs, their efficacy remains uncertain and inconclusive regarding all primary and secondary outcomes. In addition, the majority of the results are based on low-quality evidence.

4.2.1 Comparison with existing literature on injury risk reduction

Riley et al. [40] suggested that if a random-effect approach is used, the pooled result must be interpreted as the average intervention effect across studies, rather than the common effect. Previous meta-analyses have not reported prediction intervals, hence, an appropriate comparison is not possible. Therefore, we can only compare our point estimates with those reported in the literature. In contrast with the currently available evidence [14-16, 41], our study included footballers of all age groups and skill levels (amateur and professional). The point estimate (RR) of 0.71 (95%CI, 0.59 to 0.85) in the current analysis is at the lower end of the ones reported in previous systematic reviews, that arrived at incidence rate ratio (IRR) of 0.73 (95%CI, 0.59 to 0.91) [41], IRR of 0.75 (95%CI, 0.57 to 0.98) [14], RR of 0.77 (95%CI, 0.64 to 0.91) [15], and IRR of 0.77 (95%CI, 0.61 to 0.97) [16]. This was to be expected as we also included interventions in children, which showed a substantially higher injury reduction of 48% [13] and 50% [39]

compared to older players. This effect was somewhat counterbalanced by the reduced effect of the programs among veterans, which was only 9%. However, the relative weight of the studies with children was higher (higher in the number of studies and participants). A previous meta-analysis [14] investigated the effect of the FIFA® exercise-based injury prevention programs on specific body regions. The observed effect on hamstring (RR 0.83 vs IRR 0.40), knee (RR 0.60 vs IRR 0.52) and ankle injuries (RR 0.73 vs IRR 0.68) was lower in the current study, but comparable to hip/groin injuries (RR 0.56 vs IRR 0.59). A likely explanation for the differing results between the reviews is that we included a higher number of studies that examined different types of programs in the analysis. We included neuromuscular training programs, which in our sub-group analysis showed a lower risk reduction in comparison to FIFA® programs. An additional explanation could be the inclusion of studies with children because injury patterns vary with age [42]. The most obvious difference from other studies was regarding hamstring injuries. The results may be expected as we did not include trials investigating the Nordic Hamstring as a single component exercise, which has been shown to be very effective for preventing hamstring injuries [43]. Moreover, in comparison to Thorborg et al. [14], we included the Bounding Exercise Program (BEP) [25], which showed very little effect in reducing these injuries.

4.2.2 Effectiveness of injury prevention programs on contact versus non-contact injuries

For the first time, this study investigated the effect of multi-component exercise-based injury prevention programs not only on non-contact but also on contact-related injuries. The point estimate (RR) for contact injuries was 0.70 (95%CI, 0.56 to 0.88). Surprisingly, the estimated effect was higher than for non-contact injuries for which the vast majority of programs are designed. Most programs include strength exercises that mostly focus on core stability. Furthermore, plyometrics (hopping, jumping, and landing) are often part of the programs. They bear the potential to improve lower leg strength, functional leg stability, and balance, thus improving the ability to absorb external forces, e.g. induced by contact. The 11+Kids [13] program also includes one exercise specifically on correct falling techniques. The point estimate (RR) for non-contact injuries in the current study was 0.78, in line with a previous study that reported a RR of 0.77 [16].

4.2.3 Effectiveness of injury prevention programs across sexes and age groups

The subgroup analysis showed a point estimate (RR) of 0.70 in male football players. These results mimic the data of Al Attar et al. study [15]. However, the estimate is slightly lower than data reported by Lemes et al. [16] showing a point estimate (RR) of 0. 68.

Regarding females, the pooled results showed a point estimate (RR) of 0.82. This result stands within the range of results presented by studies with similar inclusion criteria [15, 16]. On the other hand, the meta-analysis with the largest estimated effect [41] included RCTs which used various injury prevention strategies. In addition to physical exercises, they included studies that used braces and education as a method for prevention. Furthermore, they included studies with participants of varying background and sports (i.e., middle and high school non-footballer athletes). These dissimilarities might have caused these considerable differences. On the other hand, small differences to other reviews [15, 16] may have come from the diversity of interventions i.e., the inclusion of single component exercise-based injury prevention programs.

The subgroup analysis for age groups showed a point estimate (RR) of 0.52 in children, a RR of 0.74 in youth, 0.73 in seniors, and 0.91 in veteran football players. The point estimate in youth and seniors is homogeneous with the current available evidence [14, 41]. The low point estimate found in children may be expected by the fact that there is rarely any prior use of preventative measures at all, therefore using the program is likely to evoke the biggest benefit. Only one trial [4] assessed the effects of injury prevention programs in veteran football players. The comparably small effect in this population is likely due to the infrequent application of the program (only once a week) as well as due to relatively low compliance.

4.3 Factors to take into account when assessing prediction intervals

In the current analysis, we calculated the PIs for the main investigated outcomes. Prediction intervals resulted wider in comparison to confidence intervals. Based on this evidence, there is a lack of compelling evidence in order to affirm the certainty of preventive effects from multi-component exercise-based injury prevention programs. However, for our meta-analysis, we have to take into account that the use of prediction intervals has its shortcomings. InHount et al. [19] mentioned that they show a wider range compared with confidence intervals in the case of any heterogeneity. Our main outcome provided an I^2=80.5% which should be interpreted as high heterogeneity according to the Cochrane Handbook for Systematic Reviews of Interventions [27].

In addition, Riley et al. [40] stated that a prediction interval will be most appropriate when the studies included in the meta-analysis have a low risk of bias. However, the majority of studies in our analysis had a high risk of bias. Therefore, these shortcomings affect the use of prediction intervals in our meta-analysis.

4.4 Strengths and limitations

To the best of our knowledge, this review is the first to analyse the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups. One strength of this systematic review is that it included multiple analyses. It investigated the risk reduction for the overall number of injuries as well as of body region-specific, contact, and non-contact injuries. Subgroup analyses for age, sex, and type of program were performed, too. Additionally, the prediction intervals for the main outcomes were calculated. A further strength is the large number of participants (22,177), injuries (5080) and exposure hours (1,587,327 h) included in comparison with other reviews [14, 15, 16]. Furthermore, we followed the best practices by including only randomised and cluster-randomised controlled trials, using a risk of bias assessment and grading the quality of evidence.

This review has some limitations, mainly that > 50% of the reported effects were based on studies with a very low or low-level of evidence. The main outcome variable provided high heterogeneity among the studies (I^2=80.5%). The lack of information about compliance with the prevention program in many studies is another limitation of this review. Furthermore, there was missing information on content and compliance of the usual warm-ups/training routines of the control groups. Another limitation is the high risk of bias, especially from the “other bias” domain, with seven studies failing to report the use of an intention to treat analysis and of an adjustment for clustering. Finally, two deviations (lack of compliance analysis and modification of literature databases) from original the study protocol have to be mentioned as shortcomings of this study.

4.5 Differences between the protocol and review

Due to the lack of respective information provided in the studies a compliance analysis was impossible. We contacted the corresponding authors to provide us with this data, but within the set time of two weeks, we only received information on one of the studies. Our planned bibliographic databases for literature identification were modified during the study implementation. Due to the lack of access, we did not search in EMBASE and SPORTDiscus. However, we additionally searched in the originally unplanned database Scopus. To empower the study, although it was not registered in the protocol we assessed the quality of evidence using the GRADE approach and calculated the prediction intervals for the main outcomes.

4.6 Recommendation for future studies

Based on the data obtained, we recommend future high-quality trials to investigate the efficacy of multi-component exercise-based injury prevention programs. In upcoming studies, data on compliance and the content of the training of the control groups should be included. Adjustment for clustering and more extensive reporting of outcomes should be emphasized. In addition, it appears important to create new injury prevention programs which reflect the development and changes in football training. This should include increasing their attractiveness to promote compliance (also outside of study settings), which appears crucial to reduce injury risk. Currently, a large number of different exercises are included since it is unknown which exercises (or which combination of them) are most effective in general or in relation to specific injuries. Tailoring the exercises would potentially mean fewer injuries and more efficiency.

5 Conclusion

This meta-analysis indicated that evidence for meaningful effects of multi-component exercise-based injury prevention programs in football remains inconclusive at best. This statement is based on prediction intervals which resulted wider than the frequently employed confidence intervals, ranging from very protective effects to an increased injury risk. In addition, the quality of evidence is a major issue in existing studies. These findings call for future high-quality trials to provide more reliable evidence regarding the efficacy of injury prevention programs in football.

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Footnotes

Contributors

RO, IH and KadF conceived and designed the study. RO, IH, RM, AL, AB, DK and BSH conducted the search, study selection, data extraction and quality appraisal. IH has analysed the data. RO, IH, and KadF contributed to interpretation of data. RO drafted the manuscript with input from KadF and TM. All authors have read and approved the final manuscript.

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Conflict of interests

Rilind Obertinca, Ilir Hoxha, Rina Meha, Arber Lama, Altina Bimbashi, Dorentina Kuqi, Bujar Shabani, Tim Meyer and Karen aus der Fünten declare that they have no conflicts of interest relevant to the content of this review.

Ethics Approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Data Availability Statement

The datasets generated and/or analysed during the study implementation are available from the corresponding author upon request.

Chapter 2: Development of a new injury prevention programme (FUNBALL) and investigation of its efficacy

2.1. Rationale for the original investigation

Initially, there was no specific IPP for youth players in place before. Additionally, the challenges of compliance and long-term adherence to existing IPPs are well-documented. The primary reason cited is the absence of football-specific exercises within IPPs. Other reported reasons include time constraints, physical complaints, and a lack of awareness and knowledge about executing the programs. The present study aimed to tackle this issue by developing a more football-specific IPP in collaboration with end-users. The 'FUNBALL' programme included exercises that facilitated competition between players. Each exercise category featured two different exercises to enhance variability, and all exercises were organized into progressive levels. The ball was used as frequently as possible. Subsequently, its effectiveness was investigated in youth football leagues in Kosovo.

2.2. The efficacy of the 'FUNBALL' programme

The following section includes the submitted manuscript related to the following publication:

Obërtinca, R., Meha, R., Hoxha, I., Shabani, B., Meyer, T., & Aus der Fünten, K. (2024). Efficacy of a new injury prevention programme (FUNBALL) in young male football (soccer) players: a cluster-randomised controlled trial. *British journal of sports medicine*, 58(10), 548–555. https://doi.org/10.1136/bjsports-2023-107388

The citations and references in this section pertain solely to this manuscript and are formatted according to the requirements of *British Journal of Sports Medicine*. The numerical citations refer exclusively to the reference list within this section and do not correspond to the reference list at the end of the thesis.

Title:

Efficacy of a new injury prevention programme (FUNBALL) in young male football (soccer) players: a cluster-randomised controlled trial

Authors:

Rilind Obërtinca (0000-0002-3468-8822), PhD student [1,2]

Rina Meha (0000-0003-2586-4852), PhD student [1]

Ilir Hoxha (0000-0003-4262-1406), adjunct assistant professor [3,4]

Bujar Shabani (0000-0003-1002-6653), assistant professor [5,6,7]

Tim Meyer (0000-0003-3425-4546), full professor [1]

Karen aus der Fünten (0000-0002-6269-5069), medical doctor [1]

Author affiliations:

1. Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany
2. Department of Physiotherapy, University of Gjakova “Fehmi Agani”, Gjakova, Kosovo
3. Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, New Hampshire, United States
4. Evidence Synthesis Group, Prishtina, Kosovo
5. Faculty of Medicine, University of Prishtina, Prishtina, Kosovo
6. IFSTTAR, LBMc, Université Claude Bernard, Lyon, France
7. Department of Orthopaedic Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland, United States

Correspondence to:

Rilind Obërtinca

Institute of Sports and Preventive Medicine, Saarland

University Campus, Building B 8-2, 66123 Saarbrücken,

Germany Email: riob00001@stud.uni-saarland.de

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Abstract

Objectives: To evaluate the efficacy of a new multi-component, exercise-based injury prevention programme in 13-19 years old football players.

Methods: Two-armed cluster-randomised controlled trial with clubs as the unit of randomisation. 55 football teams from Kosovo of the Under 15, Under 17, and Under 19 age groups were randomly assigned to the intervention (INT; 28 teams) or the control group (CON; 27 teams) and were followed for one football season (August 2021 - May 2022). The INT group performed the 'FUNBALL' programme after their usual warm-up at least twice per week, while the CON group followed their usual training routine. The primary outcome measure was the overall number of football-related injuries. Secondary outcomes were region-specific injuries of the lower limbs (hip/groin, thigh, knee, lower leg, ankle, and foot), and injury severity.

Results: 319 injuries occurred, 132 in the intervention and 187 in the control group. The INT group used the 'FUNBALL' programme in 72.2% of all training sessions, on average 2.2 times per week. There was a significantly lower incidence in the intervention group regarding the overall number of injuries (incidence rate ratio 0.69, 95% CI 0.55 to 0.87), the number of thigh injuries (IRR 0.62, 95% CI 0.39 to 0.98), of moderate (time loss between 7 and 28 days) (IRR 0.65, 95% CI 0.44 to 0.97), and of severe injuries (time loss >28 days) (IRR 0.51, 95% CI 0.28 to 0.91).

Conclusion: The 'FUNBALL' programme reduced the incidence of football-related injuries among adolescent male football players, and its regular use for injury prevention in this population is recommended.

Trial registration number Clinical trials NCT05137015.

Summary box

What is already known on this topic

- Youth football (soccer) is associated with a significant injury risk.
- Various multi-component exercise-based injury prevention programmes may reduce the risk of football-related injuries, but evidence is conflicting. Implementation of and adherence to these programmes can be challenging.

What this study adds

- The 'FUNBALL' programme is an effective intervention used after the usual warm-up which lowers the injury incidence in young male football players.
- The overall injury incidence was lowered by one third when the 'FUNBALL' programme was applied for one season.
- Preventive benefits were also found for thigh injuries, and for moderate and severe time-loss injuries.
- The positive effect on injury burden led to better player availability.

How this study might affect research, practice or policy

- Male adolescent football players should be encouraged to perform the 'FUNBALL' programme at least twice per week to induce maximal benefits.
- More research is needed on the efficacy of the 'FUNBALL' programme in other age groups (senior and veteran players) as well as in female football players.
- The 'FUNBALL' programme is more football-specific compared to existing injury prevention programmes. Future studies should explore whether this aspect improves compliance and adherence compared to previous programmes.

Introduction

Youth football (soccer) is associated with a significant injury risk. The overall injury incidence in youth male football players has been reported between 2.4 and 12.0 injuries/1000 football hours.[1, 2] The majority of injuries concerns the lower extremity,[1-4] especially the thigh region.[1, 3-5] Severe injuries accounted for 21% to 37% of all injuries,[1, 3] or 0.78 injuries/1000 h.[6] This aligns with injury locations and injury severity reported in adult professional football players.[6, 7, 8]
With the aim to reduce the number of football-related injuries, many exercise-based injury prevention programmes (IPPs) have been established. Some of them targeted specific injuries e.g., adductor,[9] hamstring,[10, 11] and knee injuries.[12-14] Others aimed to reduce the overall number of lower limb injuries.[15-18] In the above-mentioned cluster randomised controlled trials (cluster-RCTs), the highest efficacy reported was a 77% reduction in injury rates.[14] Several meta-analyses supported the efficacy of IPPs.[19-21] A more cautious interpretation of their efficacy emerged recently when other meta-analyses included the calculation of prediction intervals.[22, 23] Despite available evidence of their efficacy,[9-14, 16-18, 24-26] and the importance of good compliance for injury reduction,[27-29] many studies highlighted a low programme compliance.[15, 30, 31] Efforts have been made to optimize strategies for increasing compliance and adherence.[32, 33] Nonetheless, achieving broad-scale effectiveness of IPPs remains challenging.[34-37] The main perceived barriers to low compliance and adherence include time constraints, physical complaints (e.g., fatigue and soreness) caused by exercises, lack of awareness and knowledge about the programmes' execution, and low motivation due to the absence of football-specific activities within the IPPs.[29, 32]

We developed a multi-component exercise-based IPP specifically targeting youth football players. The intention was to use as many football-specific elements as possible, based on the assumption that they increase motivation and compliance. Exercise categories were based on scientific evidence that has previously shown good efficacy in injury prevention in football. By means of a cluster-RCT, we aimed to evaluate the efficacy of the 'FUNBALL' programme to reduce injuries in 13 to 19-year-old male football players.

Methods

Study design and participants

The design of the study was a two-armed, cluster-randomised controlled trial. It was chosen to reduce contamination bias within clubs. The study is reported according to the Consolidated

Standards of Reporting Trials (CONSORT) statement for cluster-randomised trials.[38] The study protocol was registered within ClinicalTrials.gov (identifier: NCT05137015).

At the beginning of 2020, 21 football clubs (with 70 teams in total) from different regions in Kosovo that fulfilled all inclusion criteria were invited to participate in our study, with their Under 15s, Under 17s, and Under 19s male teams (**figure 1**). All teams participated either in the Super League and/or Regional Leagues, organized by the Football Federation of Kosovo. To be included teams had to: (1) be officially registered in the above-named football association, (2) train at least twice per week, and (3) participate in regular matches of the above named leagues. We excluded clubs that were already using a structured IPP. All the clubs that enrolled for the study were randomised either into the intervention or the control group. All teams from one club were randomised into the same treatment arm. Computer-generated randomisation stratified by league level (Super League or Regional League) was performed. The stratification was chosen to account for possible differences in competition level. The randomisation was performed by one researcher (RM), who was blinded to the identities of the clubs and who was not involved in the intervention.

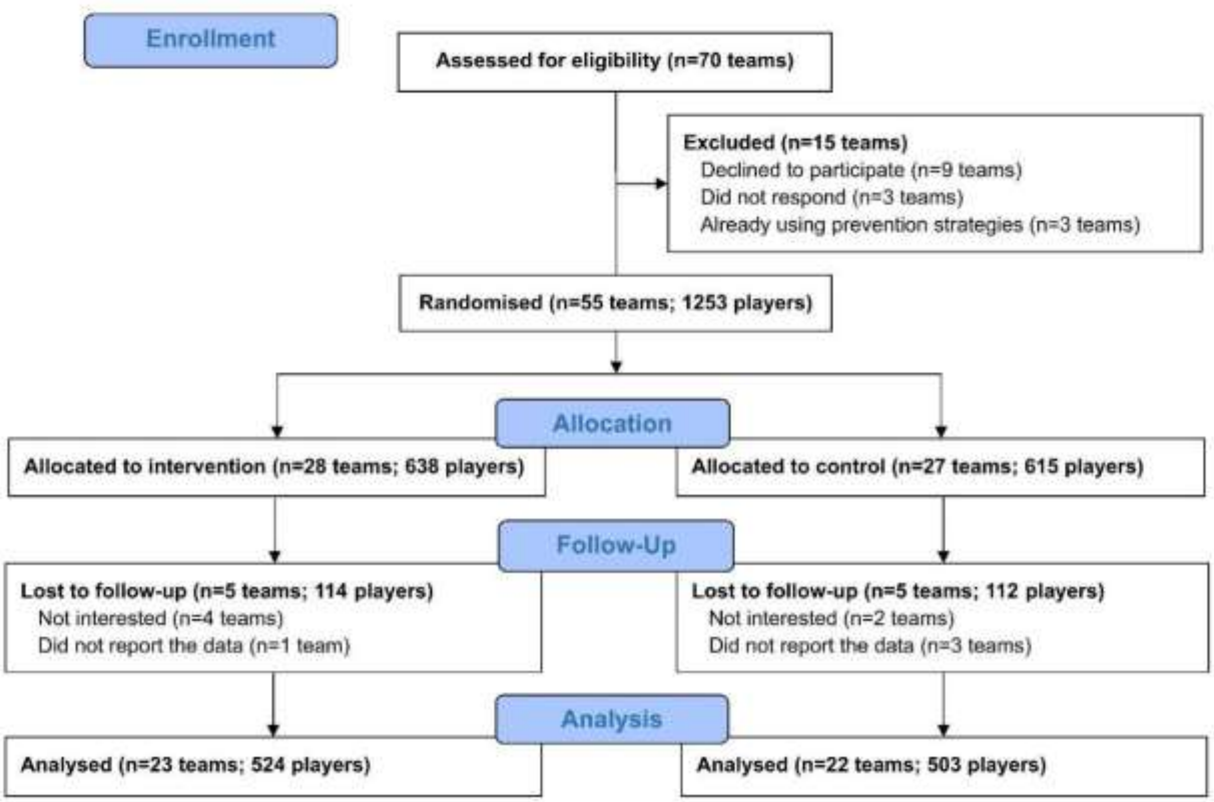

Figure 1 Consolidated Standards of Reporting Trials flow diagram of teams and players through trial.

Intervention

The intervention consisted of six **fun**damental exercise categories with the intention of preventing foot**ball**-related injuries, hence the abbreviation 'FUNBALL'. In addition, the programme contained one optional game. The following mandatory exercise categories were included: (1) balance, (2) core stability, (3) hamstring muscles eccentrics, (4) gluteal muscle activation, (5) plyometrics, and (6) running/sprinting. The optional category (7) "games" (three games included) reflected the intention to increase the attractiveness of the programme (**table 1**). Each mandatory category contained two different exercises to offer more variability. The coach was free to decide which of the two to choose for each training session. All exercises were organized in five or six progressive levels with increasing physical and cognitive difficulty, and were required to be performed in order (from 1 to 5/6). The exercises started on the first level and moved to the next one when exercises were executed with a proper technique as assessed by the coach. The programme took about 15-20 minutes to complete after familiarisation.

Table 1 Multi-component exercise-based programme 'FUNBALL' used to prevent injuries in young football players

Exercises	Repetitions/duration	Number of levels
Balance		
a. Single leg stance	2 sets x 30 seconds (on each leg)	6
b. Y-balance	3 sets x 6-8 repetitions (on each leg)	6
Core stability		
a. Plank and side plank	2 sets x 20-40 seconds (on each position)	6
b. Straight arm plank	2 sets x 8-12 repetitions	6
Hamstring muscles eccentrics		
a. Nordic Hamstring	1-2 sets x 3-10 repetitions	5
b. Hamstring walk-outs	2-3 sets x 30 seconds	5
Gluteal muscle activation		
a. Head, Shoulder, Hip, Knee,	2 sets x 6-10 repetitions	6
b. Squat lunges	2-3 sets x 8-12 repetitions	6
Plyometric		
a. Forward jumps	4 sets x 3 jumps	5
b. Skater jumps	4 repetitions (2 on each leg)	5
Running/Sprinting		
a. Diagonal running/ sprinting	3 repetitions	6
b. Forward running/ sprinting	3 repetitions	6
Games		
a. Tic-Tac-Toe	3-5 games	n.a.

b. Header game	4-5 repetitions for each player	n.a.
c. Dribbling game	3 games	n.a.

- n.a., not applicable.

Based on the latest evidence regarding the challenge of long-term adherence,[34, 35] and in accordance with what the implementation science has proposed in relation to IPP development,[33, 35] it was decided amongst the co-authors who were involved in the development of the programme (RO, RM, TM, and KadF) to include a football coach within the team for the development and refinement of the intervention. This with the intention to secure the end users' perspective throughout the whole process. The coach was not part of any team later included in the study, nor in the piloting or intervention period. In addition, a psychologist provided input for the neurocognitive demands of the programme. Prior to its implementation, the programme was piloted on two football teams. One exercise was replaced with another after the suggestions from the coaches as it was reported as too time-consuming. The pilot teams were not invited to participate in the study. To further address the compliance issue, we tried to make the programme as football-specific as possible. We introduced exercises requiring competition between the players, offered two variations for each exercise category and cognitive challenges in the majority of exercises. Furthermore, the ball was included as often as possible. Previous IPPs replaced the warm-up.[15, 16, 18] However, coaches may take this as a restriction, which may affect the long-term compliance. Therefore, we designed the 'FUNBALL' programme to be used after the usual warm-up. In order to maintain the benefits of warm-up, most of the 'FUNBALL' exercises were of relatively high intensity, especially the last three (plyometrics, running/sprinting, and games).

During the pre-season, the programme was introduced to the coaches of the intervention teams according to previous research.[15, 16] Within the club facilities, the research staff (led by first author, RO) provided instructional courses. They included theoretical and practical training. Coaches received a detailed manual of the programme and an 'on pitch' card. They were advised to use the programme at least twice a week. During the coaches' instructional courses there was a focus on the key aspects of the programme, correct postures and movement patterns. Coaches were explicitly instructed to pay attention to those aspects while performing 'FUNBALL'. The correct posture was illustrated and described in detail in the manual of the programme (**figure 2**).

Figure 2 Example of correct (left) and incorrect (right) posture alignment for one of the exercises provided in the programme (core stability; exercise a).

The intervention started one week before the clubs' first official match. Research staff visited the intervention teams several times i.e., three to four visits per team in season, to monitor the quality of programme execution. If coaches needed clarification regarding the exercises, they were advised to contact the research staff, who were continuously available throughout the study period. The coaches of the control group were instructed to perform their training as usual. Prior to the start of the intervention, we gathered more detailed information regarding the training 'routine' of control teams, by interviewing 11 of the 22 coaches. The aim was to collect information whether they performed specific exercises similar to the categories used in the programme. The control group received the programme after the end of the study.

Outcome measures

The primary outcome measure was the overall number of football-related injuries that occurred during the season. Secondary outcomes were region-specific injuries of the lower limbs (hip/groin, thigh, knee, lower leg, ankle, and foot), and injury severity (minimal, mild, moderate, and severe injuries).

Data collection procedures and definitions

The data collection procedures and definitions used in our study were in line with the consensus statement on injury definitions and data collection procedures.[39] This entailed injury definition, injury severity, mechanism of injury, injury type and location, and definitions for training and match exposure (**table 1, supplemental material**). We collected data during an entire competitive season from August 2021 to May 2022. During the preseason, the research staff and research assistants collected players' baseline characteristics. The baseline questionnaire included name, age, weight, height, playing position, history of previous injuries, and current health conditions. Throughout the competitive season, the coaches or team's physiotherapists reported to the research assistants team exposure hours, programme execution (compliance), and the new injuries that occurred on a weekly basis. If reporting was delayed for more than one week an automatic message was sent to them. The original plan was to record the injuries and individual exposure hours and report them weekly to the research team via mail. However, most coaches reported that it was too time-consuming. That led to a shift in data reporting practices. The data exchange was subsequently carried out via telephone and we collected team exposure hours instead of individual ones. When new injuries were reported, two research assistants (physiotherapists) blinded to group allocation contacted the injured players (or their parents if players were underaged) to obtain the detailed information regarding the injury and its diagnosis, by use of a standardized injury registration form.[18] To increase the accuracy of the data collection, thorough clarification of the protocols for injury classification and injury definitions was carried out for the research assistants before the season started. The exact diagnosis was required in case the player required medical treatment. Most of severe injuries (92%) were diagnosed by a physician, partially by one of the co-authors, BS, not connected to any of the clubs assigned for the study and blinded to the group allocation, or other doctors not included in the study. Additionally, the research staff visited all participating teams at the end of the season to add missing or to clarify unclear information by use of individual discussions with involved players. Data on players who dropped out or changed the teams during the season were included until then.

Eight research assistants (two physiotherapists, five students of the last year of physiotherapy school, and one strength and conditioning coach) blinded to group allocation registered the players' basic information and injuries on prepared Excel datasets. We registered all injuries reported from the start of the intervention (one week ahead of the season, 23 August 2021) until the last match of the season (22 May 2022). If players were already injured at the start of the study, they were included in the study however, that injury was excluded.

Sample size

A pre-trial sample size calculation based on the data on the incidence of injuries in adolescent male footballers was performed.[2, 3] For the primary outcome (overall injuries), we estimated that of the players in the control group will sustain an injury during the season.[2] Sample size calculation (comparison of two proportions) revealed that a total of 366 (183/arm) players are required to achieve 80% power in detecting an estimated 30% reduction in injury rate in the intervention group with an alpha level of 0.05. This is based on the assumption that the team comprises 22 players on average and taking into account an estimated design effect of 2.95. For the second outcome (region-specific injuries), 620 players are required based on the assumption that 64% of players would report a thigh, knee, or ankle injury during one season [3] and a similar reduction in injury rate and design effect as above. Based on an expected dropout rate of 30%, we aimed to recruit 806 (403/arm) football players (approximately 37 teams). We used G*Power software with two-sided Z-Test to generate the required sample size.

Statistical methods

All statistical analyses were conducted using Stata statistical software Version 17 BE (Stata Corp. Texas, United States). Descriptive statistics were reported for baseline characteristics. Continuous variables (age, height, weight, BMI, and football experience) were reported as mean and standard deviation (SD) and were checked for normal distribution. Normal distribution was determined using a histogram, QQ plot, and Shapiro-Wilk test. Incidence rate ratios (IRR) with 95% confidence intervals (CIs) were calculated according to the intention to treat principle for each outcome and compared between the intervention and control groups. We used a Poisson regression model with adjustment for cluster effect. Team was considered as cluster variable. Two-tailed p values were considered significant when the -error had a level of less than 0.05. Training exposure was calculated by multiplying the number of training sessions, training time, and mean training attendance rate.[14] Match exposure was calculated by multiplying the number of matches, match duration, and the number of players on the field.[14] The total football comprised the sum of training and match exposure hours.[14, 39] The injury incidence (IR) is presented with 95% CI and was calculated according to the formula IR=(n/e)×1000, where (n) is the number of soccer injuries, and (e) the total exposure time expressed as total hours of football exposure.[16] Injury burden was calculated as the number of days lost to injury per 1000 hours of football (“injury incidence x mean absence per injury”).[40]

Equity, diversity, and inclusion statement

The study included a variety of race/ethnicities and socioeconomic levels. The research team consists of two women and four men from different disciplines (physiotherapy, sports psychology, medicine, sports medicine, and orthopedics). It included two junior researchers (RO and RM). As our study was conducted on male football players only, we cannot extrapolate findings to female players. We expand on the exclusion of female players in the discussion.

Results

Participants

The final sample consisted of 45 football teams (1027 players), with 23 teams (524 players) in the intervention group and 22 teams (503 players) in the control group (**figure 1**). In both clusters, the dropout rate was similar (17.9% in the intervention group and 18.2% in the control group). The players in the two groups who completed the study were similar in terms of baseline characteristics (**table 2**).

Table 2 Player and injury characteristics of the intervention and control groups

Variable	Intervention group	Control group
Player characteristics		
No of teams	23	22
No of players	524	503
Mean (SD) age (years)	15.2 (1.6)	15.3 (1.6)
Mean (SD) height (cm)	171 (9.1)	172 (7.9)
Mean (SD) weight (kg)	60.2 (8.6)	60.5 (8.3)
Mean (SD) BMI (kg/m2)	20.4 (1.5)	20.3 (1.7)
Mean (SD) football experience† (years)	5.0 (1.8)	4.9 (1.6)
Exposure characteristics		
Total exposure (hours)	53 454	52 938
Match exposure (hours)	9 017	8 666
Training exposure (hours)	44 437	44 272
Injury characteristics		
No of total injuries	132	187
No of match injuries	65	91
No of training injuries	67	96
No of injured players	124	172
Injury burden* (SD) (days)	40 (3.4)	74 (5.4)

- †, football experience taking into account the years since the players has trained at least three times per week.

- *, number of injury days lost per 1000 hours.
- m, metre; kg, kilogram; BMI, body mass index.

Exposure and injury characteristics

During the season, 106 392 hours of football were recorded. The players in the intervention group were involved in 53 454 hours (44 437 training and 9 017 match hours), the players in the control group in 52 938 hours (44 273 training and 8 666 match hours) (Error! Reference source not found.). Three hundred and nineteen injuries occurred; 132 in the intervention, and 187 in the control group. The overall injury incidence rate (IR) per 1000 football hours for both groups was 2.99 (95% CI 2.68 to 3.34); the training injury IR was 1.83 (95% CI 1.57 to 2.14) and the match injury IR was 8.82 (95% CI 7.54 to 10.32). 296 (28.8%) of the 1027 players suffered an injury. The thigh was the most injured region (n=80; 25.1%; IR 0.75), followed by knee (n=62; 19.4%; IR 0.58), and ankle (n=57; 17.9%; IR 0.53). Players of the age group of the Under 19s sustained the highest number of injuries (n=122; 38.2%; IR 4.49) versus the Under 17s (n=119; 37.3%; IR 2.87), and the Under 15s (n=78; 24.5%; IR 2.06) (**table 3**). Further injury characteristics data are presented below on **table 2** and **table 3.**

Compliance to the 'FUNBALL' programme and training 'routine' of the control teams

The intervention group used the 'FUNBALL' programme in 72.2% of all training sessions, on average 2.2 times per week (**table 2, supplemental material**). The average player attendance for training sessions was 17.2 in the intervention group and 17.5 in the control group. All the interviewed coaches (n=11; 50%) of the control teams reported that they used exercises of similar categories that are contained in the 'FUNBALL' programme. The coaches of the Under 15s (n=4; 18.2%) reported they perform balance, core stability and running/sprinting exercises in their training. The coaches of the Under 17s and Under 19s teams (n=7; 31.8%) reported that they employ core stability, hamstring eccentric, plyometric, and running/sprinting exercises, but very rarely balance exercises. The majority of them applied these exercises at least once a week. However, their use was not structured with regards to the number of repetitions, duration, and types of exercises.

Efficacy of the intervention programme

For the primary outcome investigated, there was a significantly lower incidence in the intervention group for the overall number of injuries (IRR 0.69, 95% CI 0.55 to 0.87, P=0.002).

outcomes that reached significantly lower incidences in the intervention group were thigh injuries (IRR 0.62, 95% CI 0.39 to 0.98, P=0.042), moderate injuries (IRR 0.65, 95% CI 0.44 to 0.97, P=0.035), and severe injuries (IRR 0.51, 95% CI 0.28 to 0.91, P=0.024). Moreover, a significantly lower incidence was found for match (IRR 0.68, 95% CI 0.49 to 0.94, P=0.021), training (IRR 0.69, 95% CI 0.50 to 0.94, P=0.022), and traumatic injuries (IRR 0.68, 95% CI 0.53 to 0.86, P=0.002). The subgroup analysis according to age groups showed a significantly lower incidence for the overall number of injuries among the Under 15 players (IRR 0.51, 95% CI 0.32 to 0.82, P=0.005). The incidence of knee and ankle injuries did not reach significance (**table 3**). The injury burden was 40 days lost per 1000 hours in the intervention group and 74 days lost per 1000 hours in the control group (**table 2**). No harmful events associated with the use of the programme, e. g. injuries during their execution, were reported by the coaches.

Table 3 Effectiveness of 'FUNBALL' programme in adolescent male football players according to intention to treat

Variable	Intervention group		Control group			
	No. of injuries (%)	**IR (95% CI)**	**No. of injuries (%)**	**IR (95% CI)**	**IRR (95% CI)**	**P value**
Total Injuries	132 (100)	2.46 (2.08 to 2.92)	187 (100)	3.53 (3.06 to 4.07)	0.69 (0.55 to 0.87)	0.002
Under 15's injuries	29 (22)	1.43 (0.99 to 2.06)	49 (26.2)	2.77 (2.09 to 3.67)	0.51 (0.32 to 0.82)	0.005
Under 17's injuries	49 (37.1)	2.49 (1.88 to 3.30)	70 (37.4)	3.21 (2.54 to 4.05)	0.77 (0.53 to 1.11)	0.175
Under 19's injuries	54 (40.9)	3.95 (3.03 to 5.16)	68 (36.4)	5.04 (3.97 to 6.39)	0.78 (0.54 to 1.12)	0.184
Location						
Thigh	31 (23.5)	0.57 (0.40 to 0.82)	49 (26.2)	0.92 (0.69 to 1.22)	0.62 (0.39 to 0.98)	0.042
Knee	26 (19.7)	0.48 (0.33 to 0.71)	36 (19.3)	0.68 (0.49 to 0.94)	0.71 (0.43 to 1.18)	0.193
Ankle	23 (17.4)	0.43 (0.28 to 0.64)	34 (18.2)	0.64 (0.45 to 0.84)	0.66 (0.39 to 1.13)	0.138
Hip/groin	15 (11.4)	0.28 (0.16 to 0.46)	21 (11.2)	0.39 (0.25 to 0.60)	0.70 (0.36 to 1.37)	0.306
Lower leg/Achilles tendon	6 (4.6)	0.11 (0.05 to 0.24)	10 (5.4)	0.18 (0.10 to 0.35)	0.59 (0.21 to 1.63)	0.313
Foot/toe	7 (5.3)	0.13 (0.06 to 0.27)	9 (4.8)	0.17 (0.08 to 0.32)	0.77 (0.28 to 2.06)	0.605
Forearm	5 (3.8)	0.09 (0.03 to 0.22)	6 (3.2)	0.11 (0.05 to 0.25)	0.82 (0.25 to 2.70)	0.751
Hand/finger/thumb	5 (3.8)	0.09 (0.03 to 0.22)	6 (3.2)	0.11 (0.05 to 0.25)	0.82 (0.25 to 2.70)	0.751
Head/face/neck	5 (3.8)	0.09 (0.03 to 0.22)	5 (2.7)	0.09 (0.03 to 0.22)	0.99 (0.28 to 3.42)	0.988
Lower back/sacrum/pelvis	4 (3)	0.07 (0.02 to 0.19)	4 (2.1)	0.07 (0.02 to 0.20)	0.99 (0.24 to 3.95)	0.989
Shoulder/clavicle	2 (1.5)	0.03 (0.00 to 0.14)	4 (2.1)	0.07 (0.02 to 0.20)	0.49 (0.90 to 2.70)	0.417
Elbow	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Wrist	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Abdomen	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Injury mechanism						
Trauma	114 (86.4)	2.13 (1.77 to 2.56)	165 (88.2)	3.11 (2.67 to 3.63)	0.68 (0.53 to 0.86)	0.002
Overuse	18 (13.6)	0.33 (0.21 to 0.53)	22 (11.8)	0.41 (0.27 to 0.63)	0.81 (0.43 to 1.51)	0.508
Injury occurrence						
Training	67 (50.8)	1.50 (1.18 to 1.91)	96 (51.3)	2.16 (1.17 to 2.64)	0.69 (0.50 to 0.94)	0.022
Match	65 (49.2)	7.20 (5.65 to 9.19)	91 (48.7)	10.50 (8.55 to 12.89)	0.68 (0.49 to 0.94)	0.021
Injury severity						
Minimal (1–3 days)	18 (13.6)	0.33 (0.21 to 0.53)	22 (11.8)	0.41 (0.27 to 0.63)	0.81 (0.43 to 1.51)	0.508
Mild (4–7 days)	56 (42.4)	1.04 (0.80 to 1.36)	70 (37.4)	1.32 (1.04 to 1.67)	0.79 (0.55 to 1.12)	0.194

Moderate (8–28 days)	41 (31.1)	0.76 (0.56 to 1.04)	62 (33.2)	1.17 (0.91 to 1.50)	0.65 (0.44 to 0.97)	0.035
Severe (>28 days)	17 (12.9)	0.31 (0.19 to 0.51)	33 (17.6)	0.62 (0.44 to 0.87)	0.51 (0.28 to 0.91)	0.024

- IR, incidence rates, are reported per 1000 hours of football play and are unadjusted.
- IRR, incidence rate ratios, are adjusted for team.
- CI, confidence interval.

Discussion

Principal findings

The main finding of this study among young male football players is a lower overall injury incidence by one third in the group that used the ‘FUNBALL’ programme. Also, training and match injuries were lower in the intervention group when considered separately. Further relevant findings were the programme´s efficacy in reducing the incidences of one of the most frequently affected injury regions (thigh), injuries causing the longest time loss in football (moderate and severe injuries) and the injury burden. Thus, players’ availability was higher in the teams of the intervention group.

Efficacy of the programme and comparison with previous research

The ‘FUNBALL’ intervention proved to be successful in a number of aspects. The inclusion of evidence-based exercise categories for prevention of football-related injuries may be one of the main reasons. The first two categories included balance and core stability exercises. Previous studies reported on the efficacy of balance training in reducing ankle ligament injuries in football,[41, 42] and the association between impaired core stability and the development of lower extremity injuries in healthy athletes.[43] Hamstring eccentrics were also included in our programme. Their efficacy in preventing hamstring injuries is well-known.[10, 11] Even though there is limited evidence regarding the role of gluteal activation for injury prevention, there is evidence that reduced activity represents a risk factor for hamstring injuries.[44] Moreover, the crucial role of gluteal muscles in maintaining a correct knee position i.e., avoiding a dynamic knee valgus, during activities such as walking, running, jumping, and landing has been reported.[45] Incorporating plyometric exercises in IPPs has been shown to effectively decrease the risk of ACL injuries.[46] Finally, and for the first time in connection with IPPs, we introduced sprinting exercises to mitigate hamstring injury risk.[47] Combining many exercise categories makes it (more) difficult to understand which categories provide the highest benefit for reducing injury risk.

A comparison with existing studies is difficult as only very few of them considered our specific age group and male players. The preventive effect on the overall injury incidence is in accordance with two large randomised controlled trials investigating the efficacy of ‘FIFA11+’ in youth female and male football players, respectively.[16, 25] Similar to the ‘FIFA11+’ study conducted in females,[16] ‘FUNBALL’ reached a significantly positive effect on overall and severe injuries, furthermore on thigh injuries. This may be expected as this type of injury occurs more often in male footballers.[6] Owoeye et al,[25] investigated youth male football players. They reported an even higher efficacy if the 'FIFA11' programme was employed. The efficacy rate was higher for overall and match injuries compared to our findings. Their figures were 41% and 65%, respectively as compared to 31% and 32% in our study. In contrast to the 'FUNBALL' study, neither of the two abovementioned 'FIFA11+' studies reached significant effects with regards to training injuries.[16, 25] Additionally, 'FUNBALL' lowered the injury burden and the number of injuries lasting > 8 days by about 50%. This can be a highly important point, knowing that a team with lower injury burden and less severe injuries has a better chance of improved team performance.[40] Injury patterns and frequencies differ amongst different age groups and sexes. Forearm fractures are quite common in children whereas anterior cruciate ligament ruptures are more common in females aged 16 and above.[48, 49] This (together with lacking statistical power for these particular injury types) may explain why 'FUNBALL' did not show a significant preventive effect in several secondary outcomes, especially in reducing knee injuries.

The efficacy of 'FUNBALL' differed between age groups. The highest efficacy was found amongst the Under 15 players in comparison to Under 17 and Under 19 players IRR (0.51 v 0.77 and 0.78). The reason for this might be the previously mentioned fact by the interviewed coaches that they use similar categories of our programme in their training routine, especially in the older age groups. Therefore, the significant lower injury incidence due to the use of 'FUNBALL' might be mainly attributed to the large effect in the youngest age group. There were no indications that differing compliance with the conduction of the programme was a relevant confounder.

Strengths and limitations

Our study has several strengths. Firstly, the IPP was investigated through a large cluster-randomised trial. We followed good practice by cluster-randomising the clubs to avoid contamination between the control and intervention groups and by blinding the injury data collection assistants. In-season, we regularly visited the clubs without previous announcement to monitor the implementation of the programme. Moreover, we were in contact with players and their parents with regards to detailed injury information in addition to the data provided by coaches or the teams' physiotherapists. Finally, we collected detailed information from the coaches of the control group regarding the exercises that they usually perform during the season with a focus on exercises similar to those used in our intervention program. This provided a possibility of a more accurate assessment of the efficacy found in our study since an unintentional use of similar exercises would have lowered the effect of the investigated programme.

This study also has some limitations. Despite the inclusion of a football coach, we lacked the input of footballers themselves in the process of developing the intervention. We knew in advance that most of the participating clubs lacked female teams. Thus, it was a conscious decision to confine the study to male teams only. This impacts the strength of clinical recommendations for the programme implementation. We relied on an older version of the data collection methodology[39] as the planning of the study took place before a more sophisticated version[50] was available. The older version lacks some details, especially with regard to "overuse/growth-related injuries". Collecting team exposure hours instead of individual exposure hours as it was originally planned is a further limitation, since playing and training time alike can vary greatly among players.[16] After the start of the study, some barriers appeared in both groups. Four coaches of the intervention teams decided to stop the programme implementation. For them, the small number of coaching staff within the team as well as the limited time for training was the main reason for terminating the programme. In both groups, several coaches presented low motivation for providing the exposure hours and injuries that occurred. Some coaches did not report the data on a weekly basis. We excluded teams from the study if they did not provide the data for a period of four weeks. Moreover, the decision of when to progress to the next exercise level was left to the coaches without any guidance from the study assistants. In some cases, we recognised a big difference. Some clubs moved rapidly, within the first weeks of the study, to the most advanced levels while other clubs still utilised the initial levels. Finally, the additional time that is required to perform the programme (15-20 min) may be considered as a downside, which however should be weighed against less injured players. The vast majority of the limiting factors listed above potentially impact the programme's success.

Clinical implications, applicability, and future research

Reducing football-related injuries holds many benefits both individually for the players as well as for the team. A lower number of injuries, apart from the health benefits, will contribute to the performance of the teams and the financial-related aspects, but it will also increase the likelihood that the young footballers will reach their highest potential. Early adaptation to preventative exercise might, thus, be highly valuable especially at younger ages, as they may serve as a blueprint for an application later in the career. The 'FUNBALL' was investigated among adolescent male football players (aged 13 -19). Its efficacy in other age groups (seniors and veterans) or female football players was not investigated in our study. This calls for future studies to evaluate the efficacy within these groups. Furthermore, it is recommended to investigate the efficacy of the 'FUNBALL' in an even larger cohort and possibly over a longer period of time. This will enable making a comprehensive evaluation of its potential in reducing severe injuries that are less frequent such as anterior cruciate ligament (ACL) ruptures.

Conclusions

The ‘FUNBALL’ programme was effective in lowering the overall injury incidence by 31% in adolescent male football players over an entire season. This also referred to thigh injuries as one of the most frequent football-related injury type, and to moderate and severe injuries, which cause longest absence from football. Therefore, we recommend its implementation in adolescent male football players.

Ethical approval: The study was approved by the Kosovo Chamber of Physiotherapists (identifier 2020/368). All players or in case of underage players their parents gave individual written informed consent.

Data availability statement: Data are available upon reasonable request.

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Contributors: RO and KadF were responsible for the conception and design of the study. RO, RM, TM, and KadF were responsible for the development of the intervention programme. RO coordinated the study. RM was responsible for database management and contributed to the data preparation and merged the data files. IH and RO conducted the data analyses. BS and KadF checked the plausibility of injury information. RO wrote the first draft of the paper with inputs from KadF, and all authors contributed to the final manuscript.

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Competing interests: TM is chairman of UEFA´s and the German FA´s (DFB) medical committee. RO, RM, IH, BS, and KadF have no conflicts of interest directly relevant to the content of this article.

Patient and public involvement: A coach was involved in the development and refinement of the ‘FUNBALL’ programme. There was a pilot-testing period that included coaches and players of two teams (who were not eligible to take part in the actual study itself).

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Chapter 3: Epidemiology of football-related injuries in young male football players

3.1. Rationale for the investigation

The importance of epidemiological studies in injury prevention, as part of the four-step model according to van Mechelen et al. (1992), is well documented. Several epidemiological studies in youth football have been conducted. However, the sample sizes were often too small. This could lead to several limitations, such as a lack of statistical power, a lower chance of generalizing the results, difficulties in performing meaningful subgroup analyses, and a limited ability to assess rare injuries, among others. Considering the large sample size in the control arm from the study in Chapter 2, a detailed analysis was chosen.

3.2. Injuries in young male football players

The following section includes the submitted manuscript related to the following publication:

Obërtinca, R., Meyer, T., & Aus der Fünten, K. (2024). Epidemiology of football-related injuries in young male football players. An additional analysis of data from a cluster-randomised controlled trial. *Science & medicine in football*, 1–11.
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The citations and references in this section pertain solely to this manuscript and are formatted according to the requirements of *Science and Medicine in Football*. The numerical citations refer exclusively to the reference list within this section and do not correspond to the reference list at the end of the thesis.

Title:

Epidemiology of football-related injuries in young male football players. An additional analysis of data from a cluster-randomised controlled trial

Authors:

Rilind Obërtinca (0000-0002-3468-8822), [1, 2]

Tim Meyer (0000-0003-3425-4546), [1]

Karen aus der Fünten (0000-0002-6269-5069), [1]

Author affiliations:

1. Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany
2. Department of Physiotherapy, University of Gjakova “Fehmi Agani”, Gjakova, Kosovo

Correspondence to:

Rilind Obërtinca

Institute of Sports and Preventive Medicine, Saarland University, Campus, Building B 8-2, 66123 Saarbrücken, Germany; rilind.obertinca1@gmail.com

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Abstract

Football carries a high risk of injury for youth players. The aim of this study was to investigate the epidemiology of football-related injuries in young male players. The data stems from a previously conducted cluster-randomised controlled trial that investigated the efficacy of “FUNBALL”, a new injury prevention programme. This study contains the data of the 503 players of the control arm. The players belonged to 22 football teams of the Under-(U)15, U17 and U19 age groups. The time-loss injuries were recorded during the season 2021 – 2022 according to the Football Consensus Statement (Fuller et al. 2006). An analysis on the injury incidence (IR, calculated per 1000 hours of exposure), location, severity, category, and type was performed. Incidence rate ratios (IRRs) were used to compare the variables between the specific age groups. 187 injuries (96 in training and 91 in matches) occurred during 52 938 hours of exposure. The overall IR was 3.53 injuries/1000h (95% confidence intervals (CI) 3.06 to 4.07). The training IR was 2.16 injuries/1000h (95% CI 1.17 to 2.64). The match IR was 10.50 injuries/1000h (95% CI 8.55 to 12.89). In the U19s, the overall IRR was higher compared to the U17s (IRR 1.57, CI 1.12 to 2.19; p=0.008) and compared to the U15s (IRR 1.82, 95% CI 1.25 to 2.62; p=0.001). The thigh was the most commonly affected body region (IR 0.92/1000h, 95% CI 0.69 to 1.22). Muscle injuries were the most common injury type (IR 1.05/1000h, 95% CI 0.81 to 1.37). Injury burden was 74 lost days/1000h. The findings of this study indicate a lower injury incidence in youth players than in adult ones. We observed a higher injury incidence towards the older age groups.

Keywords: youth football, injury incidence

Introduction

Football (soccer) requires players to repeatedly perform sudden accelerations, decelerations, changes of direction, jumps, landings, and tackles (Krustrup et al. 2010). Such intense situations pose a risk of sustaining football-related injuries (Faude et al. 2013). Additionally, it is well-documented that there is an increased risk of sustaining injuries during the fast growth period of youth football players (Renshaw et al. 2016; van der Sluis et al. 2014). This is affected by rapid changes in hormonal release, body size, shape, composition, and neuromuscular control (Maffulli et al. 2010).

The negative influence of injuries on health and performance is well known. Injuries can outweigh the health benefits of carrying out the sport. They can lead to long-term health consequences (Maffulli et al 2010) and pose a threat to a successful football career or to prevent it to be even started (Robles-Palazón et al. 2022). Additionally, it has been reported on the strong correlation between player availability and team success (Hagglund et al. 2013). Therefore, epidemiological studies are of high importance for injury surveillance and prevention (aus der Fünten et al. 2023; van Mechelen et al. 1992). Recently, a systematic review with meta-analysis by Robles-Palazón et al. (2022) reported an overall injury incidence of 5.7 injuries per 1000 hours of exposure in youth male players. The same study reported that the majority of injuries in this population have occurred at the lower extremity, especially the thigh region, and severe injuries have accounted for 0.78 injuries per 1000 hours of exposure.

Recently, a cluster-randomised controlled trial (cluster-RCT) (Obërtinca et al. 2024) was conducted to investigate the efficacy of a new injury prevention programme called ‘FUNBALL’ in young football players. The aim of the present study is to analyse the characteristics of injuries sustained by young male footballers aged 13-19 years who were part of a cluster-RCT but not exposed to a specific injury prevention programme within their training regime.

Methods

The present study is structured according to the checklist items outlined in the International Olympic Committee Consensus Statement for reporting observational studies on injury and illness in sports (Bahr et al. 2020). The Kosovo Chamber of Physiotherapists approved the study (identifier 2020/368). Individual written informed consent was obtained from all players, or from their parents in the case of underage players.

Study design and participants

Young football players from 22 semi-professional teams in the following age groups: under (U) 15s, U17s, and U19s were included in the study. All teams participated either in the Super League (9 teams) and/or Regional Leagues (13 teams), organized by the Football Federation of Kosovo. Prior to the 2021/22 season, the teams were invited to participate in the cluster-RCT (Obërtinca et al. 2024). Throughout the season in that study, the teams were assigned to the control group. Data from this study showed that the implementation of the 'FUNBALL' programme reduced the incidence of injuries in the intervention group. Therefore, the teams of the intervention group were excluded.

Definitions and data collection

Data were collected prospectively during the season 2021 – 2022 (nine months). The data collection procedures and definitions were in line with Football Consensus Statement (Fuller et al. 2006). This entailed the injury definition "a time loss injury is an injury that results in a player being unable to take a full part in future football training or match play". The injury severity was determined by the number of days missed from full participation in team training and matches (minimal 1–3 days, mild 4–7 days, moderate 8–28 days, and severe >28 days). Further variables such as injury type, location, mechanism (traumatic or overuse), and definitions for training and match exposure were also used according to the Football Consensus Statement (Fuller et al. 2006). Basic characteristics, such as name, age, anthropometrics, and history of previous injuries, were collected by the research staff and assistants through questionnaires during the pre-season. During the season, the coaches or team's physiotherapists reported to the research assistants on a weekly basis the hours of exposure and any injuries that occurred. The hours of exposure were collected on team basis. The team registered the player as injured if he missed the subsequent training session(s) and/or game(s). Thus, injuries with zero-time loss were excluded from the analysis. Moreover, the recurrent injuries were reported as index injuries.

Initially, three research assistants (physiotherapists) oversaw 27 teams. However, as five teams dropped out during the season, the workload for each assistant decreased to approximately 7 teams per assistant. When new injuries were reported, research assistants contacted the injured players to get detailed information about the injury and diagnosis using a standardized injury registration form (Rössler et al. 2018), which also included the injury mechanism. If the players were younger than 18 years, the research assistants contacted their parents. The return to full training after the injury was then again reported by coaches or team physiotherapists. To enhance the precision of data collection, a comprehensive guidance on injury classification and definitions was provided to the research assistants prior to the start of the season. The exact diagnosis was required in case the player required medical treatment. A more detailed description of injury surveillance has been presented elsewhere (Obërtinca et al. 2024).

Statistical analysis

All statistical analyses were conducted using Stata statistical software (Version 17 BE, Stata Corp., Texas, United States) and descriptives analysed with MS Excel (Version 16.75.5, Microsoft Corp., Redmond, WA, USA). Continuous variables (age, height, weight, BMI, and football experience) were reported as mean and standard deviation (SD). Training and match, and total hours of exposure were calculated according to previous research (Fuller et al. 2006; Kiani et al. 2010). Training exposure was calculated by multiplying the number of training sessions, duration, and mean number of players attending. Match exposure was calculated by multiplying the number of matches, duration, and number of players participating. Total football exposure included both training and match hours. The injury incidence (IR) is presented with 95% confidence intervals (CIs) and was calculated according to the formula $IR=(n/e)\times1000$, where (n) is the number of football injuries, and (e) the total hours of exposure (Soligard et al. 2008). Incidence rate ratios (IRRs) with 95% CI were calculated for the following variables: overall, match, and training injuries, injury locations, severity, categories, and types using Poisson regression. IRRs were compared between the specific age groups. The dependent variables in the model were the number of all or specific injuries. The model was adjusted for the total exposure time of each specific age group to account for varying age-dependent exposure durations. The model's output was expressed using the IRR option. Mean days lost for injuries for each variable were reported with median and ranges. Injury burden was calculated as the number of days lost due to injury per 1000 hours of exposure ("injury incidence x mean absence per injury") (Hagglund et al. 2013). Players' (match and training) availability was calculated as "Σ of player match/training opportunities (= no of team matches/trainings x squad size) – Σ of player match absences due to injury or illness", and expressed as the average season match availability in percentage (Hagglund et al. 2013). The significance level was set at $p < 0.05$.

Results

Participants and exposure characteristics

In the present study, the data of 503 male football players (mean age 15.3 ± 1.6 years; height 172 ± 7.9 cm, and weight 60.5 ± 8.3 kg) was included. They participated in the U15 (n=204), U17 (n=190), and U19 (n=109) teams. Data of an entire football season (nine months) were analysed. The average number of weekly training sessions was 2.9 ± 0.2 for U15s, 3.1 ± 0.3 for U17s, and 3.3 ± 0.3 for U19s. Game frequency varied based on the league: Super League teams played 24 matches for U15s, 24 matches for U17s, and 30 matches for U19s, while Regional League teams played 22 matches for U15s, 32 matches for U17s, and 30 matches for U19s. Further data on hours of exposure and baseline characteristics are presented in **Table 1**.

Table 1 Player, exposure, injury characteristics, and player availability.

Player characteristics	
No of teams	22
No of players	503
Under-15	204
Under-17	190
Under-19	109
Mean (SD) age (years)	15.3 (1.6)
Mean (SD) height (cm)	172 (7.9)
Mean (SD) weight (kg)	60.5 (8.3)
Mean (SD) BMI (kg/m2)	20.3 (1.7)
Mean (SD) football experience† (years)	4.9 (1.6)
Exposure characteristics	
Total exposure (hours)	52 938
Match exposure (hours)	8 666
Training exposure (hours)	44 273
Injury characteristics	
No of total injuries	187
No of match injuries	91
No of training injuries	96
No of injured players	172
Injury burden* (days)	74
Cumulative time loss (days)	
Total injuries	3924
Thigh injuries	583
Knee injuries	1708
Ankle injuries	329

Other injuries	1304
Player availability	
Mean (SD) match availability (%)	96 (2.9)
Mean (SD) training availability (%)	95 (3.0)

*†, football experience taking into account the years since the players has trained at least three times per week; *, number of injury days lost per 1000 hours of exposure; SD, standard deviation; m, metre; kg, kilogram; BMI, body mass index. All reported injuries are time-loss injuries that occurred during the 2021/22 football season.*

Availability and overall, match, and training injuries

187 football-related injuries (resulting in a cumulative time loss of 3924 days) were recorded during the season. The mean of lost days per injury was 21 (median 9, range 1–291 days) (**Table 2**).

Table 2 Injury number, incidence (injuries/1000h), and mean days lost: overall and age-specific, occurrence, location, severity, category, and type.

	Number of injuries (%)	IR (95% CI)	Mean days lost (median, range)
Total Injuries	187 (100)	3.53 (3.06 to 4.07)	21 (9, 1–291)
Injury occurrence			
Training	96 (51.3)	2.16 (1.17 to 2.64)*	24 (7, 1–291)
Match	91 (48.7)	10.50 (8.55 to 12.89)*	18 (12, 1–262)
Injury location			
Thigh	49 (26.2)	0.92 (0.69 to 1.22)	12 (13, 1–32)
Anterior thigh	18 (36.7)	0.34 (0.21 to 0.53)	10 (7, 2–32)
Posterior thigh	31 (63.3)	0.58 (0.41 to 0.83)	13 (14, 2–29)
Knee	36 (19.3)	0.68 (0.49 to 0.94)	48 (7, 1–291)
ACL ruptures	4 (2.1)	0.07 (0.02 to 0.20)	269 (267, 251–291)
Ankle	34 (18.2)	0.64 (0.45 to 0.84)	10 (7, 1–32)
Hip/groin	21 (11.2)	0.39 (0.25 to 0.60)	16 (11, 1–86)
Lower leg/Achilles tendon	10 (5.4)	0.18 (0.10 to 0.35)	25 (14, 4–96)
Foot/toe	9 (4.8)	0.17 (0.08 to 0.32)	21 (6, 3–48)
Forearm	6 (3.2)	0.11 (0.05 to 0.25)	23 (23, 18–27)
Hand/finger/thumb	6 (3.2)	0.11 (0.05 to 0.25)	12 (12, 10–15)
Head/face/neck	5 (2.7)	0.09 (0.03 to 0.22)	3 (1–4)
Lower back/sacrum/pelvis	4 (2.1)	0.07 (0.02 to 0.20)	24 (22, 5–45)
Shoulder/clavicle	4 (2.1)	0.07 (0.02 to 0.20)	39 (34, 4–84)
Elbow	1 (0.5)	0.01 (0.00 to 0.13)	41 (n.a.)
Wrist	1 (0.5)	0.01 (0.00 to 0.13)	2 (n.a.)
Abdomen	1 (0.5)	0.01 (0.00 to 0.13)	20 (n.a.)
Injury severity			
Minimal (1–3 days)	22 (11.8)	0.41 (0.27 to 0.63)	2 (2, 1–3)

Mild (4–7 days)	70 (37.4)	1.32 (1.04 to 1.67)	6 (6, 4–7)
Moderate (8–28 days)	62 (33.2)	1.17 (0.91 to 1.50)	17 (16, 9–27)
Severe (>28 days)	33 (17.6)	0.62 (0.44 to 0.87)	74 (46,29–291)
Injury category			
Muscle/tendon	63 (33.7)	1.19 (0.92 to 1.52)	15 (14, 1–46)
Joint (non-bone) and ligament	61 (32.6)	1.15 (0.89 to 1.48)	36 (9, 1–291)
Contusions	33 (17.7)	0.62 (0.44 to 0.87)	6 (4, 1–18)
Fractures and bone stress	17 (9.1)	0.32 (0.19 to 0.51)	34 (26, 7–96)
Laceration/skin lesion	8 (4.3)	0.15 (0.07 to 0.30)	5 (5, 1–7)
Central/peripheral nervous system	3 (1.6)	0.05 (0.01 to 0.17)	3 (3, 1–4)
Other	1 (0.5)	0.01 (0.00 to 0.13)	3 (n.a.)
Unknown	1 (0.5)	0.01 (0.00 to 0.13)	16 (n.a.)
Injury type			
Muscle tear/strain/cramp	56 (30)	1.05 (0.81 to 1.37)	15 (14, 1–39)
Ligament /sprain	45 (24.1)	0.85 (0.63 to 1.13)	34 (7, 1–291)
Hematoma/bruise/effusion	32 (17.1)	0.60 (0.42 to 0.85)	6 (4, 1–18)
Fracture	17 (9.1)	0.32 (0.19 to 0.51)	34 (26, 7–96)
Cartilage/meniscus lesion	9 (4.8)	0.17 (0.08 to 0.32)	45 (47, 5–86)
Tendon tear/tendinitis/bursitis	9 (4.8)	0.17 (0.08 to 0.32)	25 (14, 4–64)
Abrasion	5 (2.7)	0.09 (0.03 to 0.22)	6 (6, 1–7)
Dislocation/subluxation	4 (2.1)	0.07 (0.02 to 0.20)	22 (12, 4–61)
Laceration	4 (2.1)	0.07 (0.02 to 0.20)	4 (4, 2–6)
Concussion	3 (1.6)	0.05 (0.01 to 0.17)	3 (3, 1–4)
Tooth damage	1 (0.5)	0.01 (0.00 to 0.13)	3 (n.a.)
Other	1 (0.5)	0.01 (0.00 to 0.13)	43 (n.a.)
Unknown	1 (0.5)	0.01 (0.00 to 0.13)	16 (n.a.)
Injury mechanism			
Traumatic	165 (88.2)	3.11 (2.67 to 3.63)	21 (9, 1–291)
Contact	84 (50.9)	1.58 (1.28 to 1.96)	18 (7, 1–291)
Non-contact	81 (49.1)	1.53 (1.23 to 1.90)	24 (14, 2–271)
Overuse/growth related	22 (11.8)	0.41 (0.27 to 0.63)	23 (7, 3–86)

*IR, incidence rate, reported per 1000 hours of exposure; CI, confidence interval; n.a., not applicable, *significant difference ($p < 0.05$) between match and training injury incidence, incidence rate ratio (IRR) 4.84 (95% confidence interval (CI): 3.63 to 6.45; p-value < 0.001). All reported injuries are time-loss injuries that occurred during the 2021/22 football season.*

The injury burden was 74 lost days per 1000 hours of exposure. The mean player match availability was 96%, training availability was 95% (**Table 1**). The overall IR was 3.53 injuries/1000h (95% CI 3.06 to 4.07). 49% of the injuries were sustained in matches (IR 10.50/1000h, 95% CI 8.55 to 12.89) and 51% during training sessions (IR 2.16/1000h, 95% CI 1.17 to 2.64) (**Table 2** and **Figure**

1). The incidence rate in the match was almost 5 times higher compared to the training (IRR 4.84, 95% CI 3.63 to 6.45; $p < 0.001$) (**Table 2**).

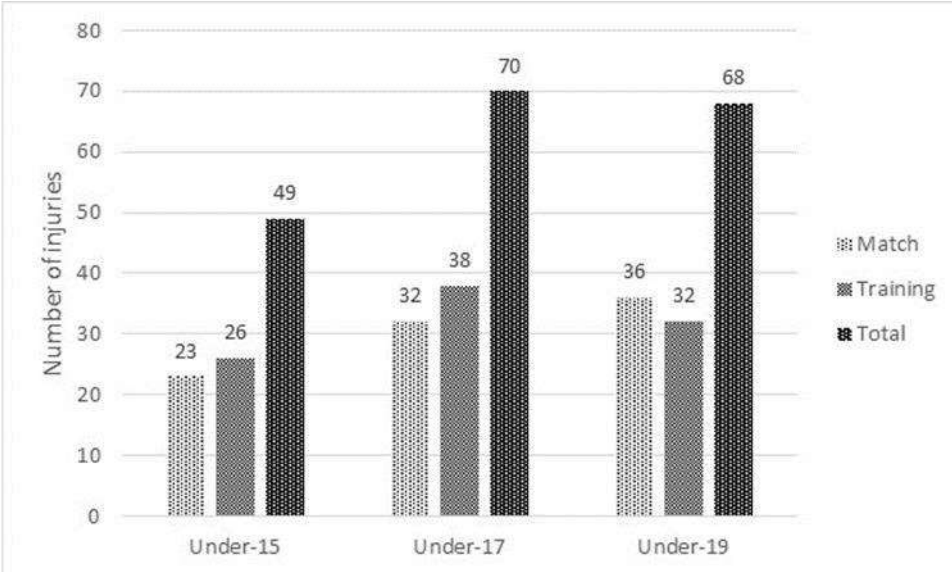

Figure 1 *Number of overall, match, and training time-loss injuries according to age group*

Location and severity

64% of the injuries affected either the thigh (26%), the knee (19%) or the ankle (18%). Knee injuries caused the highest number of days lost per injury, with a mean of 48 (median 7, range 1–291 days). Almost 49% of the injuries lasted up to 7 days. Severe injuries accounted for less than 18% (**Table 2**).

Category and type

A total of 82% of injuries were muscle/tendon injuries (33%), joint (non-bone) and ligament injuries (30%), and contusions (19%). Of all injury variables, joint (non-bone) and ligament injuries were responsible for the longest duration of days lost per injury, with a mean of 36 (median 9, range 1–291 days). The most commonly injury types were muscle tear/strain/cramp injuries (30%), ligament sprains (24%), and hematoma/bruises/effusions (18%). Cartilage and meniscus lesions took the longest time to return to play, with a mean of 45 days (median 47, range 5–86 days) (**Table 2**).

Mechanism of overall injuries

The vast majority of injuries were traumatic in nature (88%), contrasted with overuse injuries (12%). 51% of traumatic injuries were contact-related (**Table 2**).

Injury data according to specific age-groups

Players of the U19s displayed the highest incidence rate (IR 5.04/1000h, 95% CI 3.97 to 6.39) (**Figure 2**).

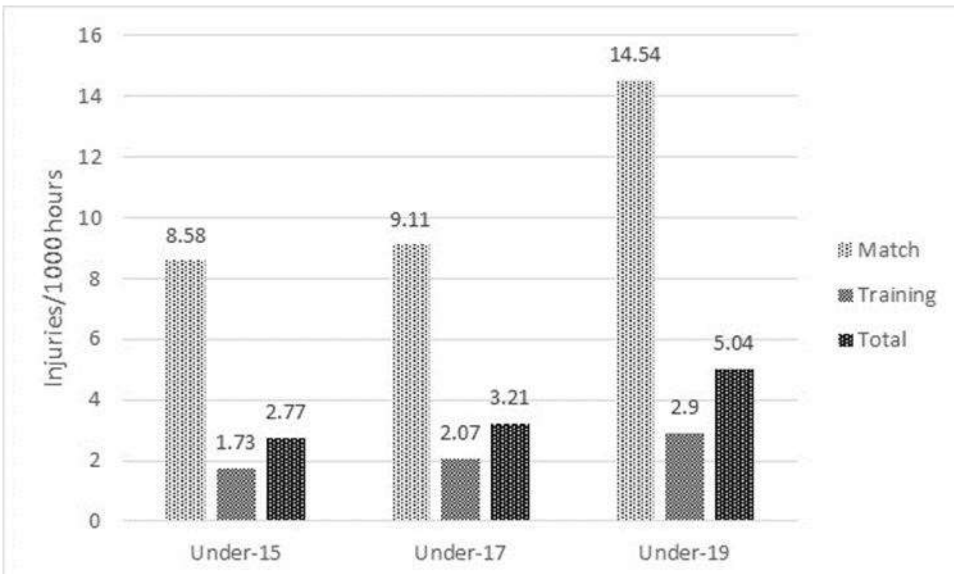

Figure 2 *Overall, match, and training injury incidence rates (injuries/1000h) according to age group.*

It was significantly higher compared to the U17s (IRR 1.57, 95% CI 1.12 to 2.19; p=0.008) and to the U15s (IRR 1.82, 95% CI 1.25 to 2.62; p=0.001). The U19s suffered the most from thigh (IR 1.48/1000h, 95% CI 0.95 to 2.29) and knee injuries (IR 1.03/1000h, 95% CI 0.61 to 1.75). Moreover, they experienced muscle and ligament injuries as the most common injury types (IR 1.63/1000h, 95% CI 1.07 to 2.47 and IR 1.18/1000h, 95% CI 0.72 to 1.93, respectively). The incidence of fractures was highest in the players of the U15s (IR 0.45/1000h, 95% CI 0.22 to 0.90). When comparing the U19s to the U17s, the U19s had a higher incidence rate for hematoma/bruise/effusions (IRR 2.59, 95% CI 1.17 to 5.70; p=0.018). The oldest age group had a significantly higher incidence rate for thigh injuries (IRR 2.38, 95% CI 1.14 to 4.97; p=0.021), moderate injuries (IRR 2.10, 95% CI 1.10 to 3.99; p=0.025), and muscle injuries (IRR 2.05, 95%

CI 1.05 to 4.02; p=0.035), compared to the youngest age group. No significant differences were found between the U17s and U15s (**Table 3** and **Table 4**). Further data on mean and median lost days per injury for each variable are presented in the **Table 3**.

Table 3 Descriptive injury data for specific age-groups

	Under-15		Under-17		Under-19	
	Number of injuries (%)	**Mean days lost (median, range)**	**Number of injuries (%)**	**Mean days lost (median, range)**	**Number of injuries (%)**	**Mean days lost (median, range)**
Total injuries	49 (26.2)	15 (7, 1–84)	70 (37.4)	21 (12, 1–291)	68 (36.4)	25 (9, 1–271)
Match injuries	23 (46.9)	15 (8, 1–84)	32 (45.7)	16 (7, 3–61)	36 (52.9)	23 (14, 2–271)
Training injuries	26 (53.1)	14 (7, 1–43)	38 (54.3)	26 (12, 3–291)	32 (47.1)	28 (7, 1–262)
Injury location						
Thigh	11 (22.5)	8 (5, 2–18)	18 (25.7)	12 (13, 3–29)	20 (29.4)	14 (15, 2–32)
Anterior thigh	6 (54.5)	8 (5, 3–17)	6 (33.3)	8 (6, 3–16)	7 (35)	15 (14, 2–32)
Posterior thigh	5 (45.5)	9 (5, 2–18)	12 (66.6)	14 (15, 6–29)	13 (65)	13 (15, 3–23)
Knee	9 (18.4)	12 (6, 3–43)	13 (18.6)	41 (7, 3–291)	14 (20.6)	76 (34, 3–271)
ACL ruptures	–	–	1 (1.4)	291 (n.a.)	3 (4.4)	261 (262, 251–271)
Ankle	10 (20.4)	8 (7, 1–31)	14 (20)	9 (7, 4–28)	10 (14.7)	13 (11, 5–32)
Hip/groin	4 (8.2)	11 (8, 1–29)	9 (12.9)	19 (12, 6–86)	8 (11.8)	14 (10, 4–39)
Lower leg/Achilles tendon	3 (6.1)	18 (14, 6–35)	3 (4.3)	50 (46, 9–96)	4 (5.9)	12 (12, 4–23)
Foot/toe	3 (6.1)	44 (43, 41–48)	2 (2.9)	19 (19, 3–34)	4 (5.9)	4 (4, 3–6)
Forearm	2 (4.1)	23 (23, 20–26)	3 (4.3)	22 (20, 18–27)	1 (1.5)	26 (n.a.)
Hand/finger/thumb	3 (6.1)	12 (11, 10–15)	3 (4.3)	10 (12, 7–13)	–	–
Head/face/neck	1 (2)	4 (n.a.)	1 (1.4)	3 (n.a.)	3 (4.4)	2 (2, 1–2)
Lower back/sacrum/pelvis	–	–	2 (2.9)	26 (26, 7–45)	2 (2.9)	21 (21, 5–36)
Shoulder/clavicle	2 (4.1)	44 (44, 4–84)	1 (1.4)	61 (n.a.)	1 (1.5)	7 (n.a.)
Elbow	–	–	1 (1.4)	41 (n.a.)	–	–
Wrist	–	–	–	–	1 (1.5)	2 (n.a.)
Abdomen	1 (2)	22 (n.a.)	–	–	–	–
Injury severity						
Minimal (1–3 days)	8 (16.3)	2 (3, 1–3)	5 (7.1)	3 (3, 3)	9 (13.2)	2 (2, 1–3)
Mild (4–7 days)	18 (36.7)	6 (6, 4–7)	28 (40)	6 (6, 4–7)	24 (35.3)	6 (6, 4–7)
Moderate (8–28 days)	15 (30.6)	17 (15, 9–26)	23 (32.9)	15 (15, 9–27)	24 (35.3)	18 (17, 9–27)
Severe (>28 days)	8 (16.3)	44 (42, 29–84)	14 (20)	68 (47, 28–291)	11 (16.2)	104 (49, 32–271)

Injury category						
Muscle/tendon	15 (30.6)	13 (13, 2–35)	23 (32.9)	14 (13, 6–46)	25 (36.8)	16 (15, 4–39)
Joint (non-bone) and ligament	16 (32.7)	11 (7, 1–43)	23 (32.9)	35 (9, 4–291)	22 (32.4)	55 (18, 2–271)
Contusions	6 (12.2)	4 (4, 1–7)	11 (15.7)	6 (4, 3–13)	16 (23.5)	6 (5, 2–18)
Fractures and bone stress	8 (16.3)	36 (26, 10–84)	8 (11.4)	32 (24, 7–96)	1 (1.5)	26 (n.a.)
Laceration/skin lesion	3 (6.1)	6 (6, 4–7)	3 (4.3)	6 (6, 4–7)	2 (2.9)	3 (3, 2–4)
Central/periph. nervous system	1 (2)	4 (n.a.)	1 (1.4)	3 (n.a.)	1 (1.5)	2 (n.a.)
Other	–	–	–	–	1 (1.5)	1 (n.a.)
Unknown	–	–	1 (1.4)	16 (n.a.)	–	–
Injury type						
Muscle tear/strain/cramp	14 (28.6)	14 (13, 2–35)	20 (28.6)	13 (13, 6–29)	22 (32.4)	16 (15, 6–39)
Ligament/sprain	14 (28.6)	9 (7, 1–31)	15 (21.4)	29 (7, 4–291)	16 (23.5)	61 (14, 2–271)
Hematoma/bruise/effusion	6 (12.2)	4 (4, 1–7)	10 (14.3)	6 (6, 3–13)	16 (23.5)	6 (5, 2–18)
Fracture	8 (16.3)	36 (26, 10–84)	8 (11.4)	32 (24, 7–96)	1 (1.5)	26 (n.a.)
Cartilage/meniscus lesion	–	–	4 (5.7)	46 (46, 6–86)	5 (7.4)	45 (49, 5–84)
Tendon tear/tendinitis/bursitis	1 (2)	6 (n.a.)	5 (7.1)	38 (46, 9–64)	3 (4.4)	11 (7, 4–23)
Abrasion	3 (6.1)	6 (6, 4-7)	2 (2.9)	6 (6, 4–7)	–	–
Dislocation/subluxation	1 (2)	11 (n.a.)	2 (2.9)	37 (37, 12–61)	1 (1.5)	4 (n.a.)
Laceration	–	–	2 (2.9)	5 (5, 3–6)	2 (2.9)	3 (3, 2–4)
Concussion	1 (2)	4 (n.a.)	1 (1.4)	3 (n.a.)	1 (1.5)	2 (n.a.)
Tooth damage	–	–	–	–	1 (1.5)	1 (n.a.)
Other	1 (2)	43 (n.a.)	–	–	–	–
Unknown	–	–	1 (1.4)	16 (n.a.)	–	–
Injury mechanism						
Traumatic	45 (91.8)	14 (7, 1–84)	60 (85.7)	19 (11, 3–291)	60 (88.2)	27 (11, 1–271)
Contact	22 (48.9)	16 (7, 1–84)	30 (50)	25 (7, 3–291)	32 (53.3)	12 (6, 1–84)
Non-contact	23 (51.1)	13 (10, 1–48)	30 (50)	14 (13, 4–47)	28 (46.7)	45 (11, 5–271)
Overuse/growth related	4 (8.2)	22 (20, 3–43)	10 (14.3)	32 (26, 4–86)	8 (11.8)	13 (7, 4–36)

n.a., not applicable. All reported injuries are time-loss injuries that occurred during the 2021/22 football season.

Table 4 Incidence rates and incidence rate ratios between specific age-groups

	Under-15 (1)	Under-17 (2)	Under-19 (3)	(3) vs (2)	(3) vs (1)	(2) vs (1)
	IR (95% CI)	IR (95% CI)	IR (95% CI)	IRR (95% CI) p value	IRR (95% CI) p value	IRR (95% CI) p value
Total injuries	2.77 (2.09 to 3.67)	3.21 (2.54 to 4.05)	5.04 (3.97 to 6.39)	1.57 (1.12 to 2.19) p=0.008*	1.82 (1.25 to 2.62) p=0.001*	1.16 (0.80 to 1.66) p=0.433
Match injuries	8.58 (5.70 to 12.91)	9.11 (6.44 to 12.88)	14.54 (10.49 to 20.16)	1.60 (0.99 to 2.56) p=0.054	1.69 (1.00 to 2.85) p=0.048*	1.06 (0.62 to 1.81) p=0.827
Training injuries	1.73 (1.18 to 2.54)	2.07 (1.51 to 2.85)	2.90 (2.05 to 4.11)	1.40 (0.87 to 2.24) p=0.161	1.68 (0.99 to 2.81) p=0.051	1.20 (0.72 to 1.97) p=0.480
Injury location						
Thigh	0.62 (0.34 to 1.12)	0.82 (0.52 to 1.31)	1.48 (0.95 to 2.29)	1.80 (0.95 to 3.39) p=0.071	2.38 (1.14 to 4.97) p=0.021*	1.33 (0.62 to 2.80) p=0.462
Anterior thigh	0.34 (0.15 to 0.76)	0.27 (0.12 to 0.61)	0.52 (0.24 to 1.09)	1.42 (0.51 to 3.90) p=0.500	1.13 (0.40 to 3.11) p=0.816	0.80 (0.27 to 2.46) p=0.693
Posterior thigh	0.28 (0.11 to 0.69)	0.55 (0.31 to 0.96)	0.96 (0.56 to 1.66)	1.75 (0.80 to 3.84) p=0.160	3.35 (1.19 to 9.40) p=0.022*	1.91 (0.67 to 5.42) p=0.224
Knee	0.50 (0.26 to 0.97)	0.59 (0.34 to 1.02)	1.03 (0.61 to 1.75)	1.74 (0.81 to 3.70) p=0.150	2.04 (0.88 to 4.70) p=0.096	1.17 (0.50 to 2.73) 0.717
Ankle	0.56 (0.30 to 1.05)	0.64 (0.38 to 1.08)	0.74 (0.39 to 1.37)	1.16 (0.51 to 2.60) p=0.727	1.31 (0.54 to 3.14) p=0.546	1.13 (0.50 to 2.55) p=0.761
Hip/groin	0.22 (0.08 to 0.60)	0.41 (0.21 to 0.79)	0.59 (0.29 to 1.18)	1.44 (0.55 to 3.72) p=0.455	2.62 (0.78 to 8.70) p=0.116	1.82 (0.56 to 5.91) p=0.318
Lower leg/Achilles tendon	0.16 (0.05 to 0.52)	0.13 (0.04 to 0.42)	0.29 (0.11 to 0.79)	2.16 (0.48 to 9.63) p=0.314	1.75 (0.39 to 7.80) p=0.465	0.81 (0.16 to 4.01) p=0.796
Foot/toe	0.16	0.09	0.29	3.24 (0.59 to 17.66)	1.75 (0.39 to 7.80)	0.54 (0.09 to 3.23)

	(0.05 to 0.52)	(0.02 to 0.36)	(0.11 to 0.79)	p=0.175	p=0.465	p=0.500
Forearm	0.11 (0.02 to 0.45)	0.13 (0.04 to 0.42)	0.07 (0.01 to 0.52)	0.54 (0.05 to 5.18) p=0.593	0.66 (0.05 to 7.22) p=0.730	1.21 (0.20 to 7.27) p=0.831
Hand/finger/thumb	0.16 (0.05 to 0.52)	0.13 (0.04 to 0.42)	–	–	–	0.81 (0.16 to 4.01) p=0.796
Head/face/neck	0.05 (0.00 to 0.40)	0.04 (0.00 to 0.32)	0.22 (0.07 to 0.69)	4.85 (0.50 to 46.65) p=0.171	3.93 (0.40 to 37.78) p=0.236	0.81 (0.05 to 12.94) p=0.882
Lower back/sacrum/pelvis	–	0.09 (0.02 to 0.36)	0.14 (0.03 to 0.59)	1.62 (0.22 to 11.48) p=0.631	–	–
Shoulder/clavicle	0.11 (0.02 to 0.45)	0.04 (0.00 to 0.32)	0.07 (0.01 to 0.52)	1.62 (0.10 to 25.86) p=0.734	0.66 (0.05 to 7.22) p=0.730	0.40 (0.03 to 4.46) p=0.460
Elbow	–	0.04 (0.00 to 0.32)	–	–	–	–
Wrist	–	–	0.07 (0.01 to 0.52)	–	–	–
Abdomen	0.05 (0.00 to 0.40)	–	–	–	–	–
Injury severity						
Minimal (1–3 days)	0.45 (0.22 to 0.90)	0.22 (0.09 to 0.55)	0.66 (0.34 to 1.28)	2.91 (0.97 to 8.68) p=0.055	1.47 (0.56 to 3.82) p=0.425	0.51 (0.16 to 1.54) p=0.232
Mild (4–7 days)	1.01 (0.64 to 1.61)	1.28 (0.88 to 1.86)	1.78 (1.19 to 2.65)	1.39 (0.80 to 2.39) p=0.240	0.75 (0.94 to 3.21) p=0.074	1.26 (0.69 to 2.27) p=0.444
Moderate (8–28 days)	0.84 (0.51 to 1.40)	1.05 (0.70 to 1.58)	1.78 (1.19 to 2.65)	1.69 (0.95 to 2.99) p=0.073	2.10 (1.10 to 3.99) p=0.025*	1.24 (0.64 to 2.38) p=0.514
Severe (>28 days)	0.45 (0.22 to 0.90)	0.64 (0.38 to 1.08)	0.81 (0.45 to 1.47)	1.27 (0.77 to 2.79) p=0.552	1.80 (0.72 to 4.47) p=0.205	1.42 (0.59 to 3.37) p=0.431

Injury category						
Muscle/tendon	0.84 (0.51 to 1.40)	1.05 (0.70 to 1.58)	1.85 (1.25 to 2.74)	1.76 (0.99 to 3.09) p=0.051	2.18 (1.15 to 4.14) p=0.017*	1.24 (0.64 to 2.38) p=0.514
Joint (non-bone) and ligament	0.90 (0.55 to 1.47)	1.05 (0.70 to 1.58)	1.63 (1.07 to 2.47)	1.55 (0.86 to 2.77) p=0.143	1.80 (0.94 to 3.43) p=0.073	0.16 (0.61 to 2.20) p=0.640
Contusions	0.33 (0.15 to 0.75)	0.50 (0.27 to 0.91)	1.18 (0.72 to 1.93)	2.35 (1.09 to 5.06) p=0.029*	3.49 (1.36 to 8.92) p=0.009*	1.49 (0.54 to 4.01) p=0.436
Fractures and bone stress	0.45 (0.22 to 0.90)	0.36 (0.18 to 0.73)	0.07 (0.01 to 0.52)	0.20 (0.02 to 1.61) p=0.132	0.16 (0.02 to 1.30) p=0.088	0.81 (0.30 to 2.15) p=0.673
Laceration/skin lesion	0.16 (0.05 to 0.52)	0.13 (0.04 to 0.42)	0.14 (0.03 to 0.59)	1.08 (0.18 to 6.45) p=0.934	0.87 (0.14 to 5.22) p=0.882	0.81 (0.16 to 4.01) p=0.796
Central/periph. nervous system	0.05 (0.00 to 0.40)	0.04 (0.00 to 0.32)	0.07 (0.01 to 0.52)	1.62 (0.10 to 25.86) p=0.734	1.31 (0.08 to 20.94) p=0.849	0.81 (0.05 to 12.94) p=0.882
Other	–	–	0.07 (0.01 to 0.52)	–	–	–
Unknown	–	0.04 (0.00 to 0.32)	–	–	–	–
Injury type						
Muscle tear/strain/cramp	0.79 (0.46 to 1.33)	0.91 (0.59 to 1.42)	1.63 (1.07 to 2.47)	1.78 (0.97 to 3.26) p=0.062	2.05 (1.05 to 4.02) p=0.035*	1.16 (0.58 to 2.29) p=0.675
Ligament/sprain	0.79 (0.46 to 1.33)	0.68 (0.41 to 1.14)	1.18 (0.72 to 1.93)	1.73 (0.85 to 3.49) p=0.129	1.50 (0.73 to 3.06) p=0.270	0.87 (0.41 to 1.79) p=0.703
Hematoma/bruise/effusion	0.33 (0.15 to 0.75)	0.45 (0.24 to 0.85)	1.18 (0.72 to 1.93)	2.59 (1.17 to 5.70) p=0.018*	3.49 (1.36 to 8.92) p=0.009*	1.35 (0.49 to 3.71) p=0.561
Fracture	0.45 (0.22 to 0.90)	0.36 (0.18 to 0.73)	0.07 (0.01 to 0.52)	0.20 (0.02 to 1.61) p=0.132	0.16 (0.02 to 1.30) p=0.088	0.81 (0.30 to 2.15) p=0.673

Cartilage/meniscus lesion	–	0.18 (0.06 to 0.48)	0.37 (0.15 to 0.89)	2.02 (0.54 to 7.52) p=0.294	–	–
Tendon tear/tendinitis/bursitis	0.05 (0.00 to 0.40)	0.22 (0.09 to 0.55)	0.22 (0.07 to 0.69)	0.97 (0.23 to 4.06) p=0.967	3.93 (0.40 to 37.78) p=0.236	4.05 (0.47 to 34.66) p=0.202
Abrasion	0.16 (0.05 to 0.52)	0.09 (0.02 to 0.36)	–	–	–	0.54 (0.09 to 3.23) p=0.500
Dislocation/subluxation	0.05 (0.00 to 0.40)	0.09 (0.02 to 0.36)	0.07 (0.01 to 0.52)	0.81 (0.07 to 8.91) p=0.862	1.31 (0.08 to 20.94) p=0.849	1.62 (0.14 to 17.86) p=0.694
Laceration	–	0.09 (0.02 to 0.36)	0.14 (0.03 to 0.59)	1.62 (0.22 to 11.48) p=0.631	–	–
Concussion	0.05 (0.00 to 0.40)	0.04 (0.00 to 0.32)	0.07 (0.01 to 0.52)	1.62 (0.10 to 25.86) p=0.734	1.31 (0.08 to 20.94) p=0.849	0.81 (0.05 to 12.94) p=0.882
Tooth damage	–	–	0.07 (0.01 to 0.52)	–	–	–
Other	0.05 (0.00 to 0.40)	–	–	–	–	–
Unknown	–	0.04 (0.00 to 0.32)	–	–	–	–

*IR, incidence rate are reported per 1000 hours of exposure; IRR, incidence rate ratio; CI, confidence interval; *significant difference (p < 0.05). All reported injuries are time-loss injuries that occurred during the 2021/22 football season.*

Discussion

This is the first study to describe injury incidence, severity, and burden in youth male footballers from Kosovo. The principal finding from this study was that the injury incidence in Kosovar youth male footballers was lower compared to a recent meta-analysis (Robles-Palazón et al. 2022) conducted in this population, IR 3.53 injuries/1000h vs IR 5.70 injuries/1000h. The most commonly injured body regions (thigh, knee, and ankle) comprised two-thirds of all injuries. The incidence of traumatic injuries was nearly seven times higher than that of overuse injuries.

The study revealed an almost five times higher injury incidence during matches compared to training. This is consistent with the data presented by previous football studies referring to both genders, to all age groups (children, youth, seniors, and veterans), and to all levels of play (amateurs and professionals) (Ekstrand et al. 2011; Hammes et al. 2015; Horan et al. 2023; Robles-Palazón et al. 2022; Rössler et al. 2016). The training and match availability was high, 96% and 95%, respectively. Information about player's availability in youth football is limited. To the best of our knowledge only one study reported such data (Wik et al. 2020). According to the authors, the mean player availability for training and matches was 85% and 90%, respectively. In senior football, players' availability was reported to be even lower. Hagglund et al. (2013) reported 77% for training and 86% for matches. This apparent difference might be caused by several factors. Firstly, the above-mentioned studies were conducted in an elite national football academy (Wik et al. 2020) and in the UEFA Champions League (Hagglund et al. 2013), thus at a higher level of play. The reported overall incidence rates were 7.7 and 12.0 injuries/1000h as compared to 3.53 injuries/1000h in the present study. This directly explains the higher availability in our study population. A higher playing level means increased competitiveness in training and matches, contributing to a higher incidence of injuries. Furthermore, higher demands on professional players due to the expanded fixture schedules lead to reduced recovery periods between training and competitive matches, consequently raising the injury risk (Dellal et al. 2013). Additionally, in professional setups it is likely that more injuries can be captured than in a semi-professional or even recreational setting, especially in youths (where medical staff is not always present). Consequently, these distinctive characteristics could have influenced the observed differences between the studies regarding match and training availability and the overall injury incidence.

Location and severity of football-related injuries

This study revealed similar results compared to existing evidence regarding the three most frequently affected body regions (thigh, knee, and ankle) previously reported in youth (Robles-Palazón et al. 2022) and adult male footballers alike (aus der Fünten et al. 2023). However, unlike the results presented in the meta-analysis of Robles-Palazón et al. (2022) regarding youth football, in our study knee injuries had a similar incidence compared to ankle injuries (IR 0.68 injuries/1000h vs IR 0.64 injuries/1000h). While thigh injuries occurred most frequently, knee injuries resulted in a far greater cumulative time loss in days (583 vs 1708 days). This disparity can mainly be attributed to the occurrence of severe knee injuries that included four ACL ruptures. This can be supported by comparing the medians of time losses between knee and ankle injuries. In both cases the median was 7 days. The higher incidence of knee injuries may potentially be attributed to the playing surface. All teams in our study used artificial turf for training and matches alike. The link between artificial turf especially of earlier generations as a risk factor and a higher incidence of knee injuries has been previously reported (Loughran et al. 2019; Ngatuvai et al. 2022). Both authors identified the increased traction and static position of the foot during athletic movements and contact during play on artificial turf as likely mechanisms. Additionally, playing on natural grass provides force-limiting mechanisms such as surface divoting or cleat sliding, both of which lacking on artificial turf, leading to significantly higher forces and torques (Kent et al. 2015). This potentially helps to explain the elevated rates of knee injuries. All playing grounds of the teams that participated in the study belonged to the older generations. If not the playing surface itself, but also a lack of adequate maintenance can lead to increased injury rates. Anecdotally, maintenance is likely less professional in younger age groups in Kosovo, with issues such as watering, cleaning, and brushing the playing surface. This could be attributed mainly to financial restrictions. Regular large-scale watering proves to be expensive. Additionally, the vast majority of teams lack cleaning and brushing machines for regular maintenance. Finally, clubs may prioritize other aspects over maintenance, potentially due to a lack of awareness of its importance. Prior studies have highlighted the essential role of maintaining artificial turf as a crucial element for ensuring athletes' safety (Jastifer et al. 2019).

With regards to the injury severity, minor and mild injuries that lasted maximally 7 days accounted for approximately 50% in our trial. This aligns with the findings of previous studies (Bult et al. 2018, Tears et al. 2018, and Veith et al. 2022) which reported similar proportions in youth football players. In contrast, Nilsson et al. (2016) and Renshaw et al. (2016) documented significantly lower percentages in those categories, 7% and 18%, respectively. Potential differences, such as study populations, league levels, and training methods, may have contributed to the differences observed between studies.

Category and type of football-related injuries

Several studies reported data on the category and the type of injuries in youth football. Our findings stand in line with the vast majority of available evidence (Robles-Palazón et al. 2022). Muscle/tendon injuries (specifically, muscle tear/strain/cramp) occurred most often, followed by joint (non-bone) and ligament injuries (specifically, ligament/sprain), and contusions (specifically, hematoma/bruise/effusion). Similar findings have been reported regarding injury types among adult male footballers.

Interestingly, the present study included only a limited number of concussions (n=3, IR=0.05/1000h), one in each age group. In the Kosovar football leagues', the U19 age group is the final stage of youth football before players advance to the first team. Given the intense nature and elevated skill level, particularly within the U19 category, a higher number was expected. On the contrary, research mentioned higher concussion rates in younger age groups with reduced neck muscle strength being a potential reason (Peek et al. 2022). Several factors may have contributed to this phenomenon. In a number of teams, the medical team was not present in training sessions which might have led to underdiagnosing such injuries due to the lack of professional staff as such. Research has underlined that concussions might frequently be underdiagnosed due to inconsistencies in the interpretation and reporting of the symptoms (Mooney et al. 2020). That does not only refer to the lay but also to the medical personnel. Moreover, even when medical personnel is available, a significant proportion of athletes (ranging from 20% to 60%) experiencing concussion symptoms choose not to disclose their condition to the medical staff. Players might have experienced concussions and nonetheless then participated in the following training sessions. Hence, these instances were not reported to the research staff and they were not caught as an injury, as previously also mentioned by Robles-Palazón et al. (2022).

Injuries across specific-age groups

Overall, our study revealed a higher injury incidence and an extended duration of days lost per injury towards the older age groups, particularly concerning the most commonly affected thigh, knee, and ankle. Expectedly, some injuries occurred more often in specific age groups. Footballers of the older age groups (U17s and U19s) exhibited a higher prevalence of muscle and ligament injuries alike. This

observation concurs with previously documented data concerning youth football and it might be expected as players reach a higher maturity status (Light et al. 2021; Read et al. 2018; Wik et al. 2020). Moreover, the findings suggest that as players physically mature, they experience more severe hamstring injuries. Potentially due to greater rate of force development and stronger bone-tendon structure, which is the weaker
point in the younger players, as reported by previous studies (Materne et al. 2022; Le Gall et al. 2007; Monasterio et al. 2021).

Regarding the most severe injuries, four ACL ruptures were noted. As it may have been anticipated, these injuries were sustained by players in the older age groups, with one event in the U17s and three events in the U19s. These findings indicate that ACL injuries in particular are observed more in the older age groups with similar incidence rates to that of adult players (0.07/1000h vs 0.06/1000h) (Walden et al. 2011). On the other hand, there was a notably higher incidence of fractures in younger players (aged U15 and U17). Although the instances of these injuries were not very common, they still reflect a similar pattern to what has been previously documented in youth football (Caine et al. 2022). The elevated frequency of fractures during younger ages can be attributed to a temporary shortfall in bone mass associated with longitudinal growth (Bonjour et al. 2014). Furthermore, the reduction in bone mineral density before peak height velocity has been linked to instances of sudden fracture (van der Sluis et al 2014). Prior research has indicated a higher occurrence of fractures in children compared to older players (Faude et al 2013; Rössler et al. 2016). Nonetheless, the frequency of fractures in our study population was markedly higher in contrast to the investigation conducted by Rössler et al. (2016), which focused on children aged 7 to 12 years and identified an incidence rate of 0.11 fractures per 1000 hours of exposure only compared to our 0.45 (U15s) and 0.36 (U17s) fractures per 1000 hours of exposure, respectively. This difference could potentially be attributed to the higher intensity of training and play observed in the aforementioned age groups distinguishing them from the context of children's football, especially considering that a significant portion of the fractures observed in our study were induced by traumatic contact-related situations, such as falls.

Practical relevance

The present study provides comprehensive insights into football related injuries in youth football. This may help the medical staff and coaches to know what injuries and lay-off period to expect in specific age-groups. As delineated in van Mechelen et al.'s (1992) still-standing four-step model on injury
prevention (1992), obtaining epidemiology data is the first step. Considering that the most frequent

injury types were muscle strains and ligament sprains, this highlights the need for implementing and evaluating preventative measures that might reduce the risk of those injuries. Although multi-component exercise-based injury prevention programmes targeting a broad spectrum of injuries are still considered best practice, practitioners might also consider adjusting interventions based on the age-related injury specifics outlined in this study. Preventing injuries among youth football players is essential for their holistic development and long-term athletic success (Faude et al. 2013; Obërtinca et al. 2023; Robles-Palazón et al. 2022).

Strengths and limitations

For the present study, one very important strength is the sample size compared to previous studies investigating youth football injuries. Furthermore, well-trained research assistants collected the data which strengthens the accuracy of data collection. The vast majority of injured players received an exact diagnosis provided by a doctor or physiotherapist (n = 151/187, 81%). With regards to the limitations, despite the large number of participants there was only a relatively small number of injuries despite strong data collection methods in place.

The limited number of injuries hindered especially the analysis of secondary variables such as contemplating findings within one age group. Small numbers impact negatively on the robustness of results and decrease the potential for generalizing the findings. Nonetheless, for significant variables such as overall injuries, match injuries, and training injuries, the power of analysis was much higher. An additional limitation of the study is the employment of an older version of the data collection methodology (Fuller et al 2006). The absence of detailed data on growth/maturity-related injuries poses another limitation. The present study lacked reporting recurrent injuries separately. This stemmed from the lack of official diagnosis for some minor injuries, thus making deduction too speculative. Finally, data on individual exposure hours was not gathered, which is in accordance with established consensus recommendations (Bahr et al 2020; Fuller et al. 2006). This aspect was influenced by the practical constraints faced by the participating teams, such as shortages of staff and time. Therefore, a team-oriented approach was used.

Conclusion

The present study revealed a lower injury incidence in youth male football players compared to adult players as reported in previous studies. There was a significantly higher injury incidence rate for the overall number of injuries in older youth teams with injury types and locations similar to those seen in adults. Injuries were mainly traumatic, with a slightly higher incidence of contact injuries compared to non-contact injuries. Given the negative impact of these injuries on health and performance, prevention strategies are of utmost importance. This is particularly crucial in youth football, as implementing effective prevention measures can provide a valuable framework throughout their careers.

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Chapter 4: General Discussion

4.1. Summary of findings

This thesis followed two main aims. Firstly, to provide an overview of the efficacy of existing IPPs on football-related injuries. Secondly, to develop a new IPP called 'FUNBALL' for youth football players (13-19 years old) and to investigate its efficacy.

The main findings of this thesis were:

1) If prediction intervals (PIs) are used in addition to confidence intervals (CIs) in a meta-analysis exploring the efficacy of multi-component exercise-based IPPs, the results shift from being uniformly positive to inconclusive and uncertain.

2) The 'FUNBALL' programme was successful. It reduced the incidence of football-related injuries with regards to the overall number of injuries, to thigh, moderate, and severe injuries.

3) In the players of the control arm, the incidence rate during the match was nearly five times higher compared to training. The thigh, knee, and ankle were the most commonly injured areas, making up two-thirds of all injuries. Traumatic injuries occurred nearly seven times more often than overuse injuries.

The findings presented in this thesis reveal several relevant insights for both practitioners and academic researchers.

4.2. Prevention of football-related injuries in youth players. Are we on the right track?

Despite the well-known negative impact of injuries in youth football (Larruskain et al., 2021) and the high incidence of such injuries (Robles-Palazón et al., 2022), surprisingly, no IPPs have been developed specifically for this age group. Although a few IPPs have been created for adult players, their efficacy has been investigated in youth footballers (Emery & Meeuwisse 2010; Owoeye et al., 2014; Soligard et al., 2008; Steffen et al., 2008; Walden et al., 2012). Most of these studies have reported promising results (Emery & Meeuwisse 2010; Owoeye et al., 2014; Soligard et al., 2008; Walden et al., 2012). However, Steffen et al. (2008) outlined no efficacy of 'the 11' programme. However, considering the differences in injury patterns between youth players and adults, generalizing these results is not meaningful. Moreover, based on the subgroup analysis of the meta-analysis (**Chapter 2**), the pooled results of IPPs conducted specifically in youth football once again demonstrated uncertainty regarding their overall efficacy. Therefore, the development of the ‘FUNBALL’ programme specifically for youth footballers (13-19 years old) can be highlighted as a significant achievement of the present thesis.

When discussing the trend of injury prevention in general, in recent years, the focus has shifted not only toward researching the efficacy of IPPs but also toward implementation strategies that will help increase adherence (Bruder et al., 2020; Owoeye et al., 2018; Whalan et al., 2019). This is a positive development, given that one of the biggest challenges is implementing IPPs after their efficacy has been established. A wide range of reasons for long-term adherence issues has been reported. The main ones include time constraints, physical complaints caused by specific exercises within the IPPs, lack of awareness and understanding about the programmes' execution, and low motivation stemming from the absence of football-specific activities in the IPPs (Soligard et al., 2010; Whalan et al., 2019). Whalan et al. (2019) assessed whether rescheduling Part 2 of the FIFA 11+ would affect compliance and efficacy. They found that this increased player compliance and reduced the rates of severe injuries and injury burden, thereby enhancing the efficacy of the 11+ programme. Several important issues related to long-term adherence were also addressed in the 'FUNBALL' programme, as mentioned in **Chapter 2**. This led to consistently high compliance throughout the season (unpublished data, supplementary figure 6.9). However, whether it can be effectively used in subsequent seasons warrants further investigation. In summary, a positive trend toward addressing the ‘low adherence’ issues raised in the existing literature has been observed in recent years. This trend might lead to the development of IPPs and implementation strategies that are potentially more appealing to coaches and players.

4.3. General limitations

Several methodological considerations and limitations need to be taken into account when interpreting the findings. Regarding the systematic review and meta-analysis presented in **Chapter 1**, more than half of the reported effects were based on studies with very low or low levels of evidence according to the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) system. The risk of bias was high in several domains, especially in the ‘other bias’ section. Half of the studies lacked important methodological information, such as intention-to-treat analysis and adjustments for clustering. Moreover, the primary outcome of the study, i.e. the overall number of injuries, exhibited high heterogeneity (80.5%). This indicates that the results from the included studies in the analysis are not consistent, which can impact the overall conclusions of the study.

Regarding the study presented in **Chapter 2**, “early” limitations relate to the planning phase of the ‘FUNBALL’ programme. Although the aim was to create a more football-specific programme. The development team included a football coach. However, it lacked input from footballers themselves. Additionally, the study was planned for male players only. The latter was due to the lack of a sufficient number of elite female football players. This impacts the strength of the clinical recommendations for programme implementation (Obërtinca et al., 2024). The use of an older version of the data collection methodology (Fuller et al., 2006) instead of the STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS) (Bahr et al., 2020) was chosen since the study was planned before the STROBE-SIIS became available. However, it represents a limitation, considering that the newer version offers a more detailed approach to data collection, particularly for overuse and growth-related injuries. The collection of data on a team basis rather than individual exposure hours is also a notable methodological limitation. Finally, the expected challenge of drop-outs of about 18% was also present in this study. However, it was lower to the rate reported in previous major cluster-RCTs (Soligard et al., 2008; Walden et al., 2012).

The study reported in **Chapter 3** had a few limitations as well. Despite the large number of participants and robust data collection methods, there were relatively few injuries. That limited the analysis of several secondary variables and impacted the generalizability of the findings. However, the analysis had sufficient power for key variables such as overall, match, and training injuries. Other limitations included the lack of detailed data on growth-related injuries and the absence of separate reporting on recurrent injuries due to the lack of official diagnoses.

4.4. Recommendations for future research

Based on the findings in this thesis, several future research directions are conceivable. In the meta-analysis on the efficacy of IPPs in football, the quality of evidence was identified as a serious issue in cluster-RCTs. That highlights the need for future high-quality trials. Future studies should also follow the recommendations to use 95% PIs in addition to the 95% CIs and the interpretation of results should not focus solely on point estimates, such as the risk ratio (RR). It should also consider the lower and upper ranges of estimates as this describes the range of true effects expected in future similar populations and conditions (Impellizzeri et al., 2021).

Additionally, from the **Chapter 2**, the 'FUNBALL' programme was developed to be more football-sports specific compared to existing IPPs. There is a need for continuous future developments of IPPs to reflect the evolving nature of training and the game alike. The same applies to the implementation strategies that would increase adherence, similar to the approach used by Whalan et al. (2019). While the 'FUNBALL' programme successfully reduced football-related injuries in youth male players, its efficacy cannot be generalized to other age groups or female footballers. Future studies should address these populations to investigate whether that ‘FUNBALL’ is effective for a broader range of participants.

4.5. Conclusions

Contrary to several previously conducted meta-analyses (Al Attar et al., 2016; Crossley et al., 2020; Lemes et al., 2021, Thorborg et al., 2017), the more detailed methodological approach used in **Chapter 1** revealed uncertainty regarding the efficacy of IPPs. The wide range of PIs (with the upper estimate exceeding 1), high heterogeneity between studies, and low level quality of evidence emphasize the need for careful interpretation of the results and cautious recommendations regarding their efficacy.

In the **Chapter 2**, the ‘FUNBALL’ programme reduced the incidence of football-related injuries in youth male players. This provides benefits for players and teams alike in terms of health and performance.

The detailed analysis of injury epidemiology in the control group provided comprehensive insights into football-related injuries in youth male players. This information may help medical staff and coaches to anticipate the types of injuries and the subsequent lay-off periods in these specific age groups. The data reported in **Chapter 3** showed that the most frequent injury types were muscle strains and ligament sprains. That highlights the need to implement and evaluate preventative measures that reduce the risk of these injuries.

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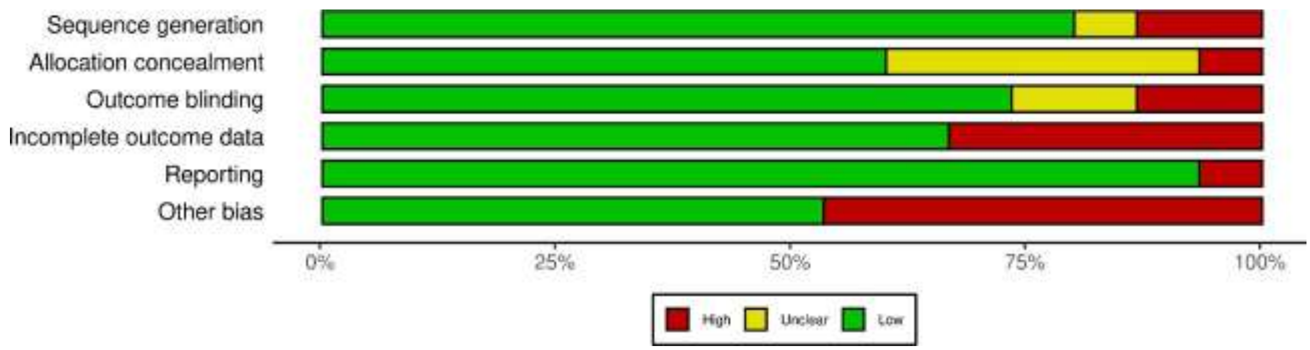
Chapter 6: Appendices

6.1. Assessment of risk of the bias of studies included in the meta-analysis (a) (chapter 1)



6.2. Assessment of risk of the bias of studies included in the meta-analysis (b) (chapter 1)

Articles	Sequence generation	Allocation concealment	Participant blinding	Outcome blinding	Incomplete outcome data	Reporting	Other bias
Emery et al. (2010)	Low	High		Low	High	Low	Low
Finch et al. (2016)	High	Low		Low	Low	Low	Low
Gilchrist et al. (2008)	Low	Low		Low	High	Low	High
Hammes et al. (2015)	High	Unclear		Unclear	Low	Low	High
Hilska et al. (2021)	Unclear	Low		Low	Low	Low	Low
Nuhu et al. (2021)	Low	Unclear		Low	Low	Low	Low
Owoeye et al. (2014)	Low	Low		High	Low	Low	High
Rossler et al. (2018)	Low	Low		Low	High	Low	High
Silvers-Granell et al. (2017)	Low	Unclear		Low	High	Low	High
Soligard et al. (2008)	Low	Low		Low	Low	Low	Low
Steffen et al. (2008)	Low	Low		Low	Low	Low	Low
Walden et al. (2012)	Low	Low		Low	Low	Low	Low
Zarei et al. (2020)	Low	Low		Low	Low	Low	High
Van de Beijsterveldt et al. (2012)	Low	Unclear		High	Low	High	High
Van de Hoef et al. (2019)	Low	Unclear		Unclear	High	Low	Low

6.3. Detailed description of injury prevention programs used, frequency and duration (chapter 1)

Study	Description of intervention	Frequency (times/week)	Duration
Emery et al. (2010)	Neuromuscular prevention training: 5 minutes warm-up including aerobic and dynamic stretch components, in addition 1010 min of neuromuscular training components (i.e., strength, agility, balance) and a 15-min home- based balance training program (using a 16-inch diameter wobble board)	at least 3x/week	15 minutes + 15 min home-based training
Finch et al. (2016)	Neuromuscular control exercise program (PAFIX): includes plyometric training, balance exercises on (un)stable surfaces, and change of direction tasks[a]	2x/week	Not provided
Gilchrist et al. (2008)	Prevent injury and Enhance Performance (PEP): the program includes: stretching, strengthening, plyometrics, agilities, and avoidance of high-risk positions depicted on a video	3x/week	< 30 minutes
Hammes et al. (2015)	This neuromuscular training program (FIFA® 11+) consists of three parts. The initial part is running exercises at slow speed combined with active stretching and controlled contacts with a partner. The second part consists of six different sets of exercises; these include strength, balance, and jumping exercises, each with three levels of increasing difficulty. The final part is speed running combined with football specific movements with bounding and plant-cut movements	1x/week	20 minutes
Hilska et al. (2021)	Neuromuscular training warm-up: 7 different exercises with focusing on motor skills and movement quality	2-3x/week	20 minutes
Nuhu et al. (2021)	FIFA 11®+[b]	at least 3x/week	20 minutes
Owoeye et al. (2014)	FIFA 11®+[b]	at least	20 minutes

		2x/week	
Rossler et al. (2018)	11+ Kids: 7 different exercises. 3 exercises focus on (unilateral) dynamic stability of the lower extremities (hopping, jumping and landing), 3 exercises on whole body and trunk strength/stability, and one exercise on falling technique.	at least 2x/week	15-20 minutes
Silvers-Granell et al. (2017)	FIFA 11®+[b]	2-3x/week	20 minutes
Soligard et al. (2008)	FIFA ®11+[b]	2-5x/week	20 minutes
Steffen et al. (2008)	The 11: 10 exercises for core stability, balance, dynamic stabilization and eccentric hamstrings strength	Every session for 15 consecutive sessions, later 1x/week	15 minutes

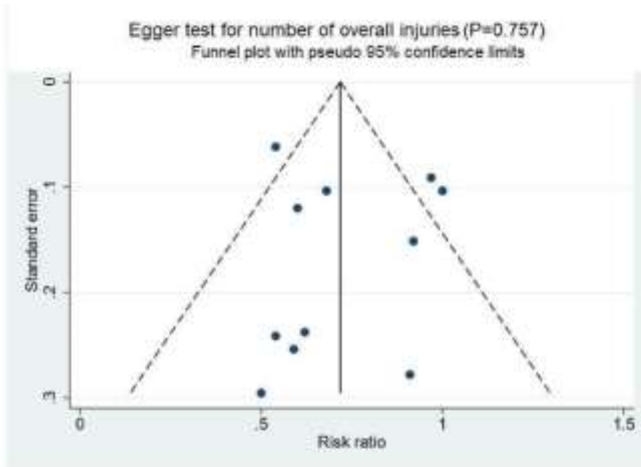
[a] information collected from the official web page of the PAFIX program

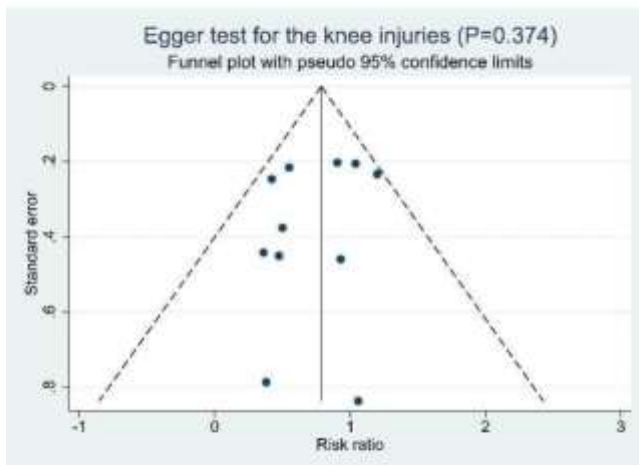
[b] description of the program is the same as mentioned by Hammes et al.

[c] description of the program is the same as mentioned by Rossler et al.

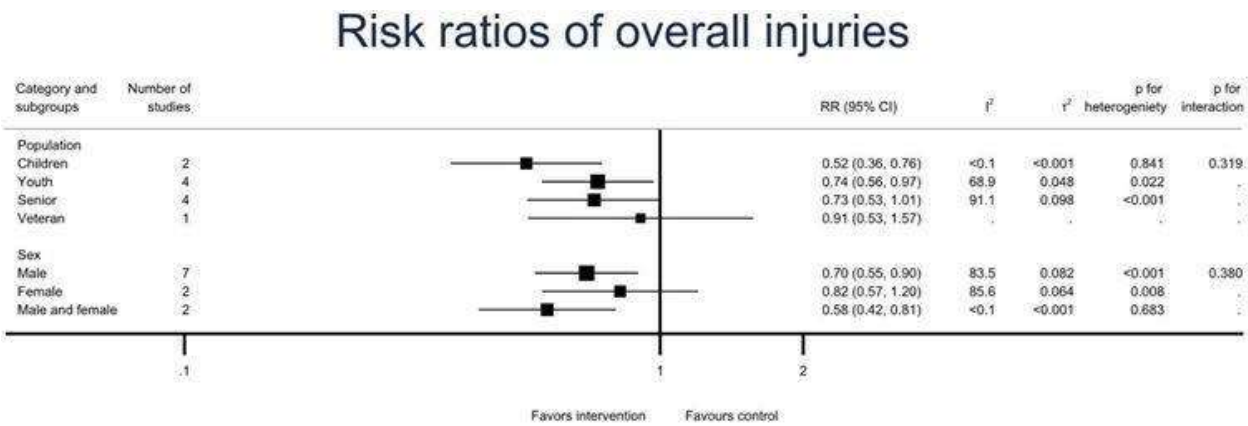
[d] description of the program is the same as mentioned by Steffen et al.

6.4. Egger test for the overall number of injuries and knee injuries (chapter 1)





6.5. Risk ratios for the overall number of injuries; sub-group analysis according to age-group and sex (chapter 1)



6.6. Definitions used in the data collection (chapter 2)

Injury	Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss fromfootball activities.
Injury severity	The number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection. ▪ Minimal injury: absence for 1-3 days ▪ Mild injury: absence for 4-7 days ▪ Moderate injury: absence for 8-28 days ▪ Severe injury: absence for >28 days.
Mechanism of injury	Traumatic: an injury resulting from a specific, identifiable event. Overuse: one caused by repeated microtrauma without a single, identifiable event responsible for the injury.
Training exposure	Team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff that are aimed at maintaining or improving players' football skills or physical condition.
Match exposure	Play between teams from different clubs.

6.7. Descriptive training participation and programme utilization (chapter 2)

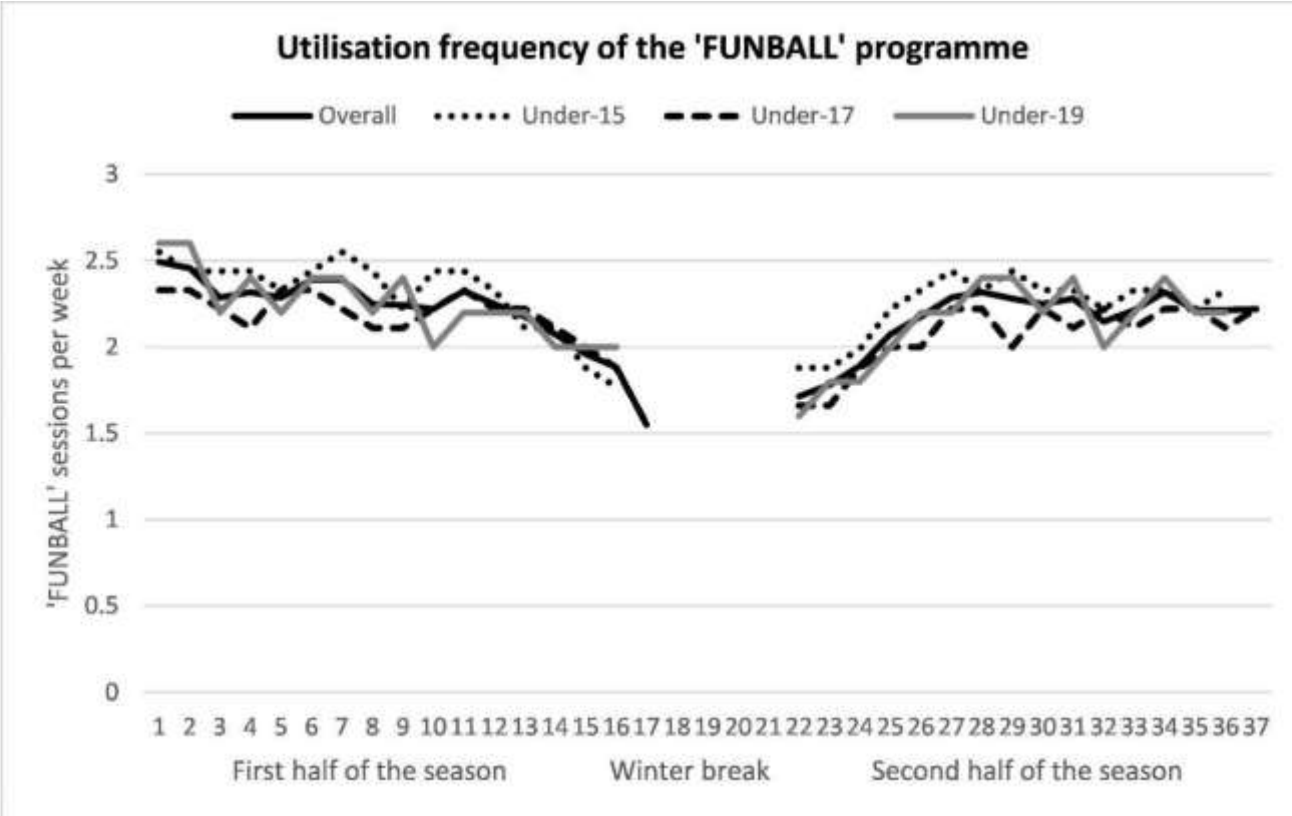
Variables	Overall
No of training sessions	2224
Average players attendance (SD)	17.2 (6.1)
Utilisation frequency	
Full season, times/week (SD)	2.2 (0.2)

6.8. Data on specific thigh (anterior and posterior) and knee (ACL and meniscus) injuries in the intervention and control group (chapter 2)

	Intervention group		Control group			
	No. of injuries (%)	**IR (95% CI)**	**No. of injuries (%)**	**IR (95% CI)**	**IRR (95% CI)**	**P value**
Thigh injuries	**n=31**		**n=49**			
Anterior thigh	11 (37.9)	0.20 (0.11 to 0.37)	18 (36.7)	0.34 (0.21 to 0.53)	0.61 (0.28 to 1.28)	0.18
Posterior thigh	18 (62.1)	0.33 (0.21 to 0.53)	31 (63.3)	0.58 (0.41 to 0.83)	0.58 (0.32 to 1.02)	0.06
Knee injuries	**n=26**		**n=36**			
ACL rupture	1 (3.8)	0.01 (0.00 to 0.13)	4 (11.1)	0.07 (0.02 to 0.20)	0.25 (0.02 to 2.21)	0.21
Meniscus tear	1 (3.8)	0.01 (0.00 to 0.13)	4 (11.1)	0.07 (0.02 to 0.20)	0.25 (0.02 to 2.21)	0.21

- IR, incidence rates, are reported per 1000 hours of football play and are unadjusted.
- IRR, incidence rate ratios, are adjusted for team.
- CI, confidence interval.

6.9. Unpublished data on the utilisation frequency of the 'FUNBALL' programme



6.10. Injury prevention programme (manual for coaches and the short version) (chapter 2)

Injury Prevention Programme

‘FUNBALL’

Manual for coaches

Development and conceptual design

M. Sc. Rilind Obërtinca, PhD. Cand. (sports physiotherapy)

Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany

Karen aus der Fünten, MD, (orthopaedic surgeon, sports medicine, manual therapy), **MChiro** Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany **Prof. Dr. Tim Meyer, MD, PhD.** (sports medicine)

Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany

In cooperation with

M. Sc. Rina Meha, PhD. Cand. (cognitive neuropsychology)

Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany **Prof. Dr. Sabine Schaefer** (movement science and sport psychology)

Institute of Sports Science, Saarland University, Saarbrücken, Germany **M. Sc. Elon Berisha** (football coach) Football Federation of Kosovo

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1. Introduction

Football is the most popular sport in the world, with 260 million male and female active participants, including ~113,000 FIFA registered professional players. Playing football is fun and can provide many health benefits, however it also presents a highinjury risk. Therefore, this program has been created by international professionals andaims to reduce football injuries for football players aged 13+.

2. General outline, content and structure of the program

The execution of the program takes around 15 minutes and should be used at least twice per week. The program will be performed in the training sessions, after the usualwarm-up. The warm-up should prepare the players for intense exercises, such as jumping and sprinting.

The program is based on scientific evidence that has previously shown good efficacy on injury prevention in football. The exercise categories address 7 aspects:

1. Balance
2. Core stability
3. Hamstring muscle eccentrics
4. Gluteal activation
5. Plyometric
6. Running/Sprinting
7. Games

The games are included with the aim to increase the attractiveness of the program. Each category contains 2 exercises and the coach is free to decide which one tochoose in every training session. All exercises are organized in five or six levels withincreasing difficulty (physically and cognitively). If players can perform a level with the correct technique, it is the coach's decision to move to the next level. The instructionsfor the players should be short, clear, and concise.

3. General guidelines of the program

- The levels should be completed in the designated order. No level should be skipped. A player can train at the 3rd level in one exercise while he is at the 1stlevel in another exercise.
- A player can start with the next level if the exercise has been carried out correctly in three successive training sessions.
- The breaks between the sets should last approximately 20-30 sec (when applicable).
- If the cone colours are replaced for numbers, the replacement becomes randomand changes in every training session.
- If numbers replace the cone colour, the numbers used should be from 1-99.
- If calculations are used in the exercises the resulting number should be singularbetween 1 and 9.
- 3-digit numbers are used in a few levels, when players are asked to react onlyto the last number.

4. Equipment

For the execution of this program, the team needs basic training equipment, such asballs, cones, hurdles, and training kits.

5. Posture

A highly important aspect of the program is good posture retention. Proper posture keeps the body structures in optimal alignment, which increases the effect of the exercises while reducing the risk of suffering an injury. The coaches should continuously pay attention to the correct posture of the footballers while performingthe exercises. The correct posture and possible errors for each exercise are describedin detail alongside the exercise description. Correct posture is more important than speed when performing each exercise.

PROGRAM EXERCISES

6.1. Balance exercises

a. Single leg stance

Correct exercise posture:

✓ Lift one leg off the ground at 90°.

✓ The position of the head, neck, back, and thighs should be in one line.

✓ The head is straight and the gaze is forward.

✓ Distribute the weight on the standing leg evenly between the heel and the balls of the foot.

Make sure to correct these errors:

Do **not** bend the hips.

Do **not** let the knee move inwards.

Do **not** lift the forefoot or heel off the ground. Do **not** lean forward.

Starting position: players are in pairs. They stand on one leg facing each other about 2 arm lengths apart. The players look straight ahead. They bend the knee of the swing leg 90°. Both players carry a ball in their hands.

Equipment needed: 1-2 balls per pair.

Level 1

Action: move the ball around the belly.

Repetition: 2 sets on each leg (30 sec. each).

Level 2

Action: same as level 1. The eyes are closed.

Repetition: 2 sets on each leg (30 sec. each).

Level 3

Action: using 1 ball, hand it to the partner at different body levels. Coach randomly instructs e.g., head, shoulder, hip, knee and feet.

Repetition: 2 sets on each leg (30 sec. each).

Level 4

Action: hand the ball to the partner in the opposite direction from the coach's instruction. When instruction is "UP" hand the ball "DOWN", and vice versa. Same applies for "LEFT" and "RIGHT".

Repetition: 2 sets on each leg (30 sec. each).

Level 5

Action: the eyes are closed. Hand the ball straight to the partner at upper body level.

Explanation: the players pass the ball when the coach instructs "PASS". Players should be of similar height.

Repetition: 2 sets on each leg (30 sec. each).

Level 6

Starting position: the distance between players is increased to 2 meters, (distance can be increased over time to 3m and 4m). There is one ball per pair.

Action: using their feet, players pass the ball to each other. The other player catches the ball with his hands.

Repetition: 2 sets on each leg (30 sec. each).

b. Y-Balance

Correct exercise posture:

✓ Lift one leg off the ground.

✓ Other foot is always in contact with the ground.

✓ The position of the head, neck, back should be in one line.

✓ Hands rest on the hips.

✓ Distribute the weight on the standing leg evenly between the heel and the balls of the foot.

Make sure to correct these errors:

Do **not** let the knee move inwards (into valgus). Do **not** lift the forefoot or heel.

Starting position: players are in pairs. They stand on one leg facing each other. The players look straight ahead. Each player stands in the middle of 3 cones or any objects available e.g., clothing of different colours. The cones are placed in a 'triangle shape' on the ground 80cm apart. Cone distance increases over levels. One cone is in front and 2 cones are behind the respective player. The colour of the cones of the players are mirroring one another, *(e.g., if the "red" colour is behind and to the left for player 1, it is also behind and to the left for player 2*).

Players remain on the same leg until the end of the set.

Equipment needed: 6 cones of 3 different colours per pair.

Level 1

Action: coach instructs the colour. The players reach the respective cone with their foot of the swing leg.

Repetition: 3 sets of 6 reps. (on each leg).

Level 2

Action: same as level 1. The eyes are closed.

Repetition: 3 sets of 6 reps. (on each leg).

Level 3

Cone distance: increased to 90cm.

Action: player 1 reaches one colour with their foot of the swing leg. Player 2 reflects the move of player 1.

Repetition: 3 sets of 6 reps. (on each leg).

Level 4

Action: coach replaces the colour of the cones for numbers, e.g. *"red"=1, "blue"=2, "yellow"=3*, and instructs the numbers. The players reach the respective cone with their foot of the swing leg.

Repetition: 3 sets of 8 reps. (on each leg).

Level 5

Cone distance: increased to 1m.

Action: same as level 4. The eyes are closed.

Repetition: 3 sets of 8 reps. (on each leg).

Level 6

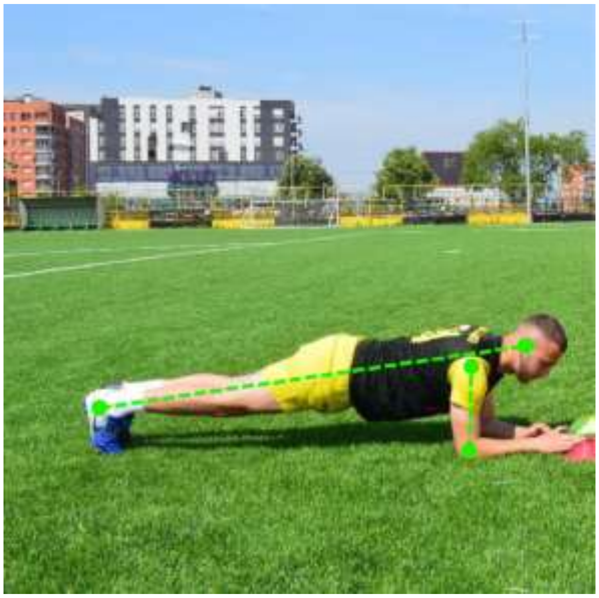
Action: coach uses calculations to have the respective instructed numbers, e.g., *(1= "red", 2= "blue", 3= "yellow"): 3-2=" red", 9-7=" blue", 1+2=" yellow").* The players reach the respective cone with their foot of the swing leg.

Repetition: 3 sets of 8 reps. (on each leg).

6.2. Core Stability exercises

a. Plank and Side Plank

Correct exercise posture:



- ✓ Place forearms on the ground.
- ✓ Forearms are parallel to your body about shoulder width apart.
- ✓ Elbows are aligned below shoulders.
- ✓ The position of the lower legs, thighs, back, neck and head should be in one line.
- ✓ Stay on the toes.
- ✓ The gaze is fixed on the ground.

Make sure to correct these errors:

Do **not** drop the head.

Do **not** drop the lower back.
Do **not** raise the buttocks.

Do **not** let the pelvis shift sideways or up/down.

Starting position: the players are in pairs. They face each other in the plank and both side plank positions (on the left and right forearm) respectively. Two cones of different colours are placed in the middle of them, shoulder width apart. Distance of the players from the cones is one hand length.

Equipment needed: 3 cones of different colour per pair.

Level 1

Action: hold the plank positions. Players begin with a side plank, then turn to the front plank and finally to the other side plank position (=one set).

Repetition: hold each of the positions for 30 sec., 2 sets.

Level 2

Action: hold the plank positions. Coach instructs a colour. The players compete to touch that cone first. They lift the arm from the ground to touch the cone.

Repetition: hold each of the positions for 30 sec., 2 sets.

Level 3

Action: same as level 2. The players compete for the colour that was not instructed.

Repetition: hold each of the positions for 30 sec., 2 sets.

Level 4

Starting position: distance of the players from the cone is increased to an arm length in front plank position. In the side plank position distance between the players remains the same

(1 hand length).

Action: same as level 3. The eyes are closed.

Repetition: hold each of the positions for 30 sec., 2 sets.

Level 5

Action: the eyes are closed. Hold the plank positions. Coach replaces the colour of the cones for numbers, e.g., *"red" =1, "yellow" =2*. Coach instructs numbers. The players compete for the colour that was not instructed.

Repetition: hold each of the positions for 30 sec., 2 sets.

Level 6

Starting position: in front of players are now placed 3 cones of a different colour. The middle cone is placed in front of the players face, other cones one hand width apart on either side.
Action: hold the plank positions. Coach replaces the colour of the cones for numbers, e.g. *"red"=2, "blue"=4, "green"=6*. Coach instructs a three-digit number. Based on the last number of the instruction, players compete for the cone represented by that number. **Repetition:** hold each of the positions for 30 sec., 2 sets.

b. Straight Arm Plank

Correct exercise posture:

- ✓ Place hands on the ground.
- ✓ Wrists, elbows and shoulders should be in one line.
- ✓ Arms are perpendicular to the body about shoulder width apart.
- ✓ The position of the lower legs, thighs, back, neck and head should be in one line.
- ✓ Stay on the toes.
- ✓ The gaze is fixed on the ground.

Make sure to correct these errors:

Do **not** drop the head.

Do **not** drop the lower back.
Do **not** raise the buttocks.

Do **not** let the pelvis shift sideways or up/down.

Starting position: the players are in pairs. They face each other in a straight arm plank position. Two (later three) cones of different colours are placed in between them. Distance of the players from the cones is one hand width.

Equipment needed: 3 cones of different colours per pair.

Level 1

Action: coach instructs the colour. Players compete to catch the cone first. At the end of the set the player with the lower score does three push-ups. If they are equal, both do three push-ups (continues in all levels).

Repetition: 2 sets (8 repetitions).

Level 2

Action: same as level 1. Players compete for the colour that was not instructed.

Repetition: 2 sets (8 repetitions).

Level 3

Action: coach replaces the colour of the cones for odd and even numbers, e.g., *"red" =even, "green" =odd.* Coach instructs three-digit numbers. If the last number is odd, players compete for the cone representing odd numbers.

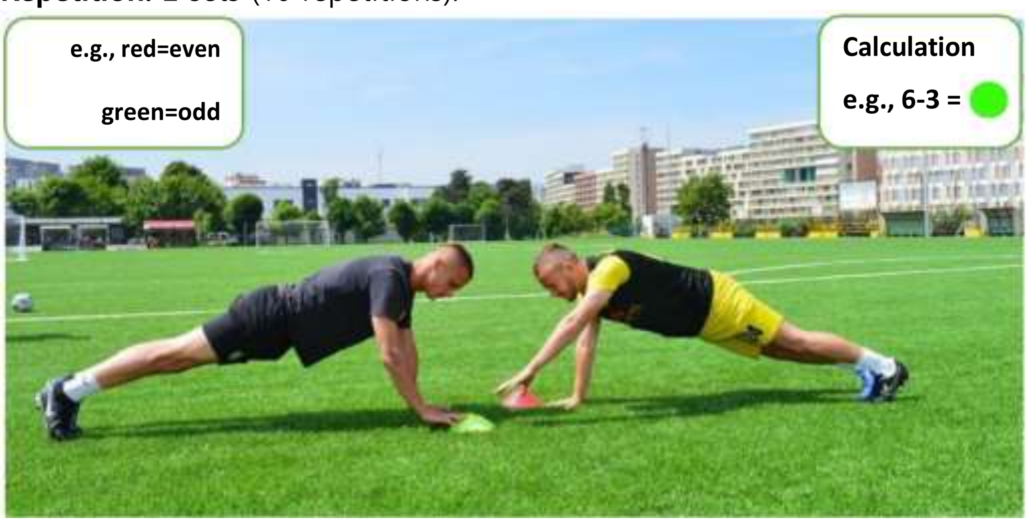
Repetition: 2 sets (10 repetitions).

Level 4

Starting position: distance of the players from the cone is increased to an arm length from the cones.

Action: coach uses a calculation to have odd and even numbers. Players compete for the cone representing odd or even numbers.

Repetition: 2 sets (10 repetitions).



Level 5

Starting position: same as level 1. Three cones of different colours are placed in between them. The middle cone is placed in front of players, other cones one hand width apart on either side.

Action: coach instructs the colour. Players compete for the colour instructed.

Repetition: 2 sets (12 repetitions).

Level 6

Action: each colour of the cones represents a specific number told previously to the players, e.g., *"red" =3, "green" =5, and "blue" =9.* Coach instructs a three-digit number. Based on the last number of the instruction players compete for the cone represented by that number.

Repetition: 2 sets of 12 repetitions.

6.3. Hamstring muscles eccentrics a. Nordic Hamstring

Correct exercise posture:

✓ Feet, lower legs, and knees stay in touch with the ground.

✓ Knees are about shoulder width apart.

✓ The position of the thighs, hips, back, neck and head should be in one line.

Make sure to correct these errors:

Do **not** drop the head.

Do **not** bend the hips.

Do **not** round the back.

Starting position: one player starts in a kneeling position with the upper body upright. The partner applies pressure to the athlete's heels/lower legs to ensure that the knees, lower legs and feet stay in touch with the ground throughout the movement.

Equipment needed: none.

Explanation: players will change the level every 6 weeks.

Level 1

Action: player leans forward in a straight line from head to knee and in a controlled manner and tries to avoid falling forward. If players cannot control the movement any further, they catch themselves on their hands.

Repetition: 1 set (5 repetitions).

Level 2

Action: same as level 1.

Repetition: 1 set (6-8 repetitions).

Level 3

Action: same as level 1.

Repetition: 1 set (10-12 repetitions).

Level 4

Action: same as level 1.

Repetition: 2 sets (6-8 repetitions).

Level 5

Action: same as level 1.

Repetition: 2 sets (8-10 repetitions).

b. Hamstring walk-outs

Correct exercise posture:

✓ Knees bent, and feet flat on the floor under the knees, shoulder width apart.

✓ Raise the hips to create a straight line from your knees to the shoulders.

Make sure to correct these mistakes:

Do **not** drop the hips.

Starting position: players are in pairs, lying on their backs. Their heads are placed close to each other. Players are facing away from each other. They are in a bridge position. The feet are planted.

Equipment needed: 1 ball per pair.

Level 1

Action: players walk forwards and backwards on their feet.

Explanation: walk forward until the legs are fully extended and the weight is supported on the heels.

Repetition: 2 sets (30 sec.).

Level 2

Starting position: same as level 1. There is one ball per pair.

Action: players walk forwards and backwards on their feet. While walking forward and backward, they hand the ball back and forth overhead to their partner using their hands.

Repetition: 2 sets (30 sec.).

Level 3

Action: coach instructs a three-digit number. While walking forward and backward, if the last number is odd or even number (known previously for the players), they hand the ball back and forth overhead to their partner using their hands, e.g., *"odd" =pass the ball, "even" =keep the ball.*

Repetition: 2 sets (30 sec.).

Level 4

Action: while walking forward and backward, they hand the ball back and forth overhead to their partner using their hands, when the coach instructs a specific number known previously to the players (5 numbers), e.g., *pass the ball only when the instruction is 1,13,24,71,99 …* **Repetition**: 3 sets (30 sec.).

Level 5

Action: coach uses a calculation to have the odd and even numbers. While walking forward and backward, they hand the ball back and forth overhead to their partner using their hands, when calculation gives an odd or even number (known previously for the players), e.g., *"odd" =pass the ball, "even" =keep the ball.*

Repetition: 3 sets (30 sec.)

6.4. Gluteal muscle activation

a. Head, Shoulder, Hip, Knee, Ankle

Correct exercise posture:

- ✓ In the front view, keep the hips, knees and feet in one line.
- ✓ Feet are shoulder width apart.
- ✓ The toes are facing forward.
- ✓ The knees should be only slightly in front of the ankle.
- ✓ Drive your hips back. Bend your hip and knee joints to 90° (squat position).
- ✓ Keep the back straight.
- ✓ Keep the feet planted (in the first three levels).

Make sure to correct these errors:

Do **not** let the knees move inwards. No **not** round the back.

Starting position: Players are in 2 long rows facing each other in the 90° squat position. They face each other about 2 arm lengths apart. The ball (or later 2 cones) lie(s) midway between each pair. On instruction of the coach players subsequently touch various parts of their own body with both hands. On a specific instruction of the coach, e.g., 'ball', players compete about catching the object on the ground first (=winner). After each catch players change their partner, e.g., losers, move one place to the left, winners moving one place to the right.

Equipment needed: 1 ball and 2 cones of different colour per pair.

Level 1

Action: coach randomly instructs the body parts: head, shoulders, hips, knees, ankles. When the instruction is 'BALL', players compete to catch it first.

Repetition: 2 sets (6 repetitions).

Level 2

Starting position: same as level 1. The ball is replaced with two cones of different colours.

Action: when the instruction is a colour, players compete to catch that cone first.

Repetition: 2 sets (6 repetitions).


Level 3

Action: same as level 2. Players compete for the cone that was not instructed.

Repetition: 2 sets (8 repetitions).


Level 4

Staring position: players tap the foot on the ground as fast as possible (with the toes moving up and down).

Action: coach replaces the colour of the cones for odd and even numbers., e.g., *"blue" =even and "green" =odd.* If the instruction is an odd number, players compete for the cone representing odd numbers.

Repetition: 2 sets (8 repetitions).

Level 5

Action: players tap the foot on the ground as fast as possible.

Each colour of the cones means a specific number told previously to the players, e.g., *"green" =4, and "blue" =7.* Coach instructs a three-digit number. Based on the last number of the instruction players compete for the cone represented by that number.

Repetition: 2 sets (10 repetitions).

Level 6

Action: players tap the foot on the ground as fast as possible.

Players touch one level down from the instruction, e.g., *"head" means touching the "shoulder" ("shoulder"="hip", "hip"="knee", "knee"="ankle", "ankle"="head").* Coach replaces the colours of the cones for odd and even numbers, e.g., *"blue"=even and "green"=odd.* If the instructionis an even number players compete for the cone representing even numbers.

Repetition: 2 sets (10 repetitions).

b. Squat Lunges

Correct exercise posture:

✓ Stand up straight and tall.

✓ The position of the back, neck and head should be in one line.

✓ Step forward with one foot until your leg reaches a 90-degree angle at hip and knee joint.

✓ Knee should be only slightly in front of the ankle.

✓ Keep the back straight.

✓ Keep the pelvis horizontal.

Make sure to correct these errors:

Do **not** touch the ground with the knee.

Do **not** let the knees move inwards.

Do **not** round the back.

Starting position: players are in pairs. They face each other about 2 arm lengths apart. In the middle of them are placed two cones of different colours. The distance between the cones is one hand width. Players rest their hands on the hips.

Equipment needed: 2 cones of different colours and 1 ball per pair.

Level 1

Action: coach instructs the colour. Players perform the lunge towards the cone with the respective colour.

Explanation: if the colour of the cone placed on the right side of the player is instructed, the player performs the lunge with the right leg. Same applies for the other side.

Repetition: 2 sets of 8 repetitions (4 should be for each leg, random order).

Level 2

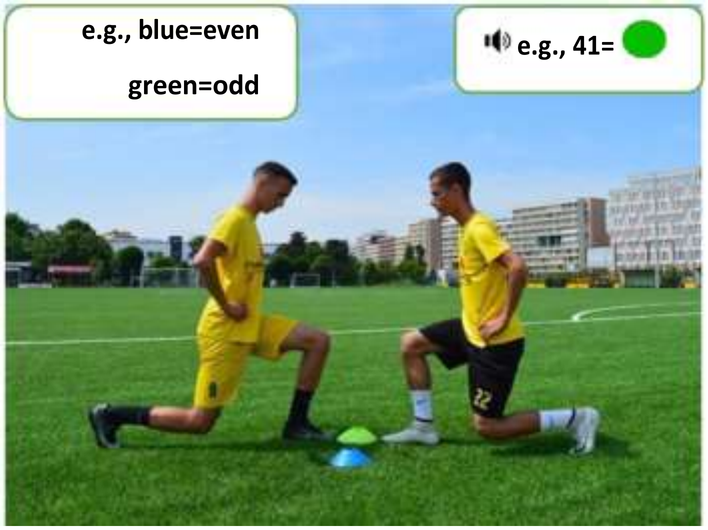
Action: same as level 1. Players perform the lunge to the colour that was not instructed.

Repetition: 2 sets (10 repetitions, 5 for each leg, random order).

Level 3

Action: coach replaces the colour of the cones for odd and even numbers, e.g., *"blue" =even and "green" =odd.* If the instruction is an odd number players perform the lunge to the cone representing odd numbers.

Repetition: 2 sets (12 repetitions, 6 for each leg, random order).



Level 4

Action: coach uses a calculation to have the odd and even numbers. Players perform the lunge to the cone representing these numbers, e.g., *"blue" =even and "green" =odd.*

Repetition: 3 sets (8 repetitions, 4 for each leg, random order).

Level 5

Starting position: same as level 1. One ball per pair.

Action: same as level 4. They hand the ball to the partner when they go in a lunge position.

Repetition: 3 sets (10 repetitions, 5 for each leg, random order).

Level 6

Action: same as level 5. The eyes are closed.

Repetition: 3 sets (12 repetitions, 6 for each leg, random order).

6.5. Plyometric exercises

a. Forward Jumps

Correct exercise posture:

- ✓ Squat down by bending knees and hips.
- ✓ Swinging arms back.
- ✓ Immediately jump forward while swinging arms forward and upward.
- ✓ Land on the balls of either both or one foot.
- ✓ Bend ankles, knees, and hips to absorb impact.

Make sure to correct these errors:

Do **not** let the knees move inwards.

Do **not** land with extended knees or on your heels.

Do **not** let your knees fall ahead of your toes.

Starting position: all players stand in one line next to each other approximately 1m apart.

Equipment needed: one ball per player.

Level 1

Action: players perform 3 forward jumps. They take off and land on both legs. They compete for the longest distance. Players can use the arms to gain movement. They walk back to the starting position to begin the next repetition.

Repetition: 4 sets (4 sets x 3 jumps).

Level 2

Action: same as level 1. They take off on one leg, landing on both legs. They immediately remove one leg of the ground to perform the next jump (same applies for three jumps). They walk back to the starting position to begin the next repetition.

Repetition: 4 sets (2 sets x 3 jumps on each leg).

Level 3

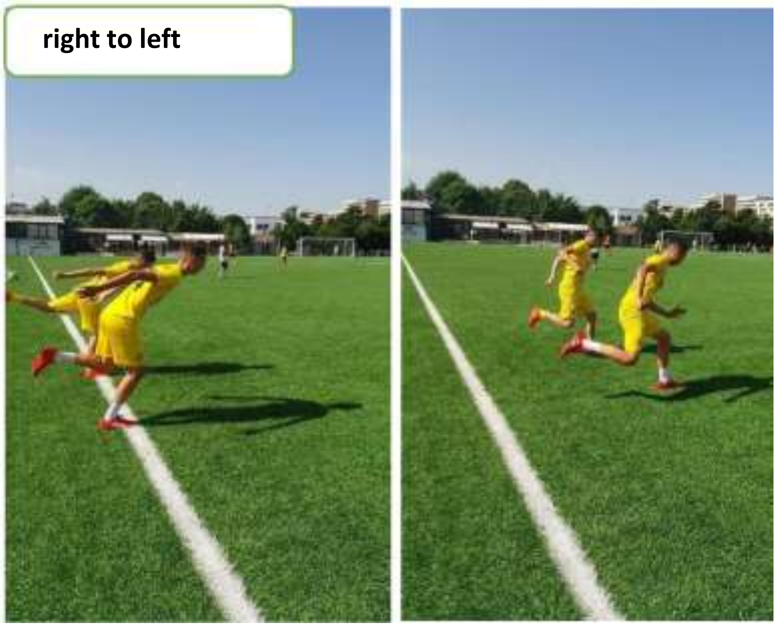
Action: same as level 1. They take off on both legs, landing on one leg. They immediately turn their foot on the ground to perform the next jump (same applies for three jumps). They walk back to the starting position to begin the next repetition.

Repetition: 4 sets (2 sets x 3 jumps on each leg).

Level 4

Action: same as level 1. They take off on one leg, landing on opposite leg, **e.g., take off with the right leg, land on the left (for three jumps).** They walk back to the starting position to begin the next repetition.

Repetition: 4 sets (2 sets x 3 jumps on each leg).



Level 5

Action: same as level 1. Players have the ball in their hands. They take off and land on the same leg **e.g., take off with the right leg, land on the right (for three jumps).** They walk back to the starting position to begin the next repetition.

Repetition: 4 sets (2 sets x 3 jumps on each leg).

b. Skater Jumps

Correct exercise posture:

- ✓ Start with feet hip width apart and knees slightly bent.
- ✓ Push off your right foot to hop to your left and vice versa.
- ✓ Bend ankles, knees, and hips to absorb impact.

Make sure to correct these errors:

Do **not** let the knees move inwards.

Do **not** land with extended knees or on your heels.

Do **not** let your knees fall ahead of your toes.

Starting position: 2 cones placed 1.25m apart are (for lateral jumps) the starting point of this exercise with the player standing between them. 7 cones at 1m distance diagonally, and approx. 1m width apart are placed for skater jump exercises. Behind the cones 3 hurdles (or other objects) of 15cm height are placed, at approx. 40 cm distance. Prepare 3-4 courses depending on team size (max 6 players per course).

Equipment needed: 9 cones, 3 hurdles and 2 balls for each course.

Level 1

Action: player performs 6 lateral jumps between the first two cones at 'start line'. Player moves on to perform the skater jumps diagonally and finally jumps over the hurdles with two legs. The player jogs back to the starting position. Next player starts when the previous player finishes skater jumps.

Repetition: 4 repetitions.

Level 2

Action: same as level 1. The player jumps over the hurdles on one leg. The leg remains the same.

Repetition: 4 repetitions (2 on each leg).

Level 3

Starting position: cone width distance for lateral jumps at the starting line is increased to 1.5m. Cone distance for skater jumps is increased to 1.25m (diagonally). Each course/station has one ball.

Action: same as level 2. Players additionally take the ball in their hands. Players jog to the starting point to hand the ball to the next player.

Explanation: in order to save time, use more balls, so that the next player can start if the previous player finishes their skater jumps.

Repetition: 4 repetitions (2 on each leg).

Level 4

Action: same as level 3. The player completes the course as fast as possible and hands the ball to the next in line who does the same. Teams of the different courses compete for the fastest finish. One competition finishes when all players of a course/station have finished one cycle (repetition).

Explanation: number of players per team is set by the coach (max 6 players per team).

Repetition: 4 repetitions (2 on each leg).

Level 5

Starting position: there are two balls per course.

Action: same as level 4. Players carry 2 balls, one in each hand.

Repetition: 4 repetitions (2 on each leg).

5.6. Running/Sprinting exercises

Correct exercise posture:

- ✓ Keep your upper body straight.
- ✓ Hips, knees and feet should be aligned.
- ✓ Keep your pelvis horizontal.
- ✓ Swing your arms sideways to the body (**not** across the body).

Make sure to correct these errors:

Do **not** let the legs cross the midline.
Do **not** let the knees move inwards.

a. Diagonal running

Starting position: coach and players stay 10m apart facing each other. Players stay in pairs. Coach stands in the middle of 2 cones of different colour, placed 10m apart. Another cone (exact colour does not matter) is placed between the coach and the players. Players in pair jog (medium jog speed) next to each other straight forward to the cone placed in front of them. Coach instructs a command (verbal or visual) just before players reach the cone and players run with high speed diagonally to one of the cones located on the side of the coach,competing to reach the cone first.

Equipment needed: 5 cones and two balls for each course.

Level 1

Action: the coach provides verbal instruction of one cone's colour, e.g., "red" or "blue". Players continue to run to the instructed cone, competing to reach the cone first.

Remark: Without a proper warm-up **avoid** competition. If there is no competition, players should increase their running speed with each repetition.

Repetition: 3 repetitions per pair.

Level 2

Action: same as level 1. Players run to the cone that was not instructed.

Repetition: 3 repetitions per pair.

Level 3

Starting position: coach holds 2 different coloured cones in his hands behind his back. The colours are matched by the cones on the ground.

Action: coach provides a visual instruction. He shows the players one of the cones. Players run to the same colour of the cone on the ground.

Repetition: 3 repetitions per pair.

Level 4

Action: same as level 3. Players run to the cone that was not instructed.

Repetition: 3 repetitions per pair.

Level 5

Action: coach provides a verbal instruction. He replaces the colour of the cones for odd or even numbers, e.g., *"blue"=odd, "red"=even*. Players run to the cone representing those numbers.

Repetition: 3 repetitions per pair.

Level 6

Starting position: each player has a ball at their feet.

Action: the coach uses a calculation to have the odd and even numbers. Players dribble the ball to the cone representing those numbers.

Repetition: 3 repetitions per pair.

b. Forward running

Starting position: 2 cones with different colours are placed at a distance of 10m. Players are separated into 2 groups (max 6 players per group). They stand behind the first cone. Playersin pairs of different teams start jogging and pushing each other side-to-side at shoulder level from the first cone until they reach about midway between the cones, when there is an instruction from the coach.

Equipment needed: 2 cones and two balls for each course.

Level 1

Action: when coach instructs "FORWARD" or "BACKWARD", players run forward to the cone placed in front ("forward") of them or behind ("backward") of them respectively as fast as they can, competing to reach the cone first.

Remark: without a proper warm-up avoid competition. If there is no competition, players should increase their running speed with each repetition.

Repetition: 3 repetitions per pair.

Level 2

Action: coach instructs one of the cone's colours, e.g., *"red" or "green".* Players run forward to the instructed cone.

Repetition: 3 repetitions per pair.

Level 3

Action: same as level 2. The players run forward to the cone that was not instructed.

Repetition: 3 repetitions per pair.

Level 4

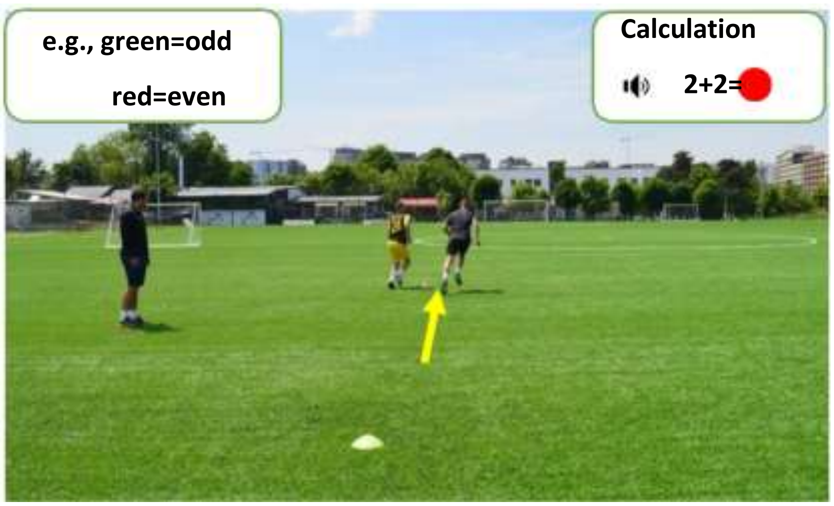
Action: coach replaces cones' colours for odd or even numbers, e.g., *"green"=odd, "red"=even.* Coach instructs numbers. Players run forward to the cone representing those numbers.

Repetition: 3 repetitions per pair.

Level 5

Action: coach uses a calculation to have the odd and even numbers. Players run to the cone representing those numbers.

Repetition: 3 repetitions per pair.



Level 6

Starting position: Each player has a ball at their feet.

Action: coach instructs a three-digit number. If the last number is odd players run to the cone representing odd numbers.

Repetition: 3 repetitions per pair.

5.7. Games

a. Tic-Tac-Toe

Starting position: 9 hoops in 3 rows are placed in close proximity on the field to mark a tic-tac-toe field. Two cones are placed at a distance of 5m on opposite sites from this field represent the starting point of two teams. Teams consist of four players each. The first three players of each team have a training kit in their hand.

Equipment needed: 9 hoops, 2 cones (placed on the ground), and 6 training kits of two colours (one colour for each team).

Action: the first player in line from each team starts to run to the hoops and places the training kit in one of the hoops. Then they run back as quick as they can, return to the cone marking the starting point and provides a high five to the next player in line, who then starts towards the hoops. Aim is to create 3 kits in a row with your kits of your own colour. The 3 in a row can be diagonally, horizontally or vertically. If the game is not finished after the first three players, the fourth player starts moving one kit to an empty hoop set previously by his teammates, until the game ends.

Remark: players are not allowed to waste time at the hoops. They have to place/move the kit and return to their teammates as soon as possible.

Repetition: 3-5 games.

b. Header Game

Starting position: players are divided into 2 groups (max. 6 players per group). Both groups stand on the goal line 5 m away from either side of the post. The group that heads first, places one player (header) 5-8m into the penalty box line facing the other group members. The other group places one in the goal (role of the goalkeeper).

Equipment needed: balls, 5x2m goal (in case of its absence it can be modified, e.g., with cones or training kit).

Action: the player who heads first stands about 8m away from his teammates in the penalty box. Then the first mate of his team at the goal line throws a ball towards the header of his own team aiming for the 5m line. The header tries to score, which the other team tries to prevent by the allocated goalkeeper. The header then becomes the goalkeeper. The goalkeeper becomes the last in the line. Then the action repeats itself. **Repetition:** 4 to 5 repetitions for each player.

c. Dribbling game

Starting position: There is a cone marking the starting point. At 3m distance from that cone6 cones are placed in a row on the ground each 1m apart. Players are divided into teams of 4 players. They stand behind each other at the starting cone.

Equipment needed: 7 cones and one ball per team.

Action: the first player dribbles through the cones without touching the cones with either the ball or feet as fast as possible. The player then runs back to the first cone, gives the 2nd playera high five and hands the ball over to the 2nd player. The 2nd player performs the same action and so forth. Teams compete on who finishes the dribbling first.

Repetition: 3 games.

6.11. Injury prevention programme (the short version/on pitch card) (chapter 2)

6.12. Full published texts relevant to this thesis

The following appendices represent the fully published versions of the texts relevant to this thesis and are presented in chronological order of publication date.

Sports Medicine (2023) 53:837–848
https://doi.org/10.1007/s40279-022-01797-7

SYSTEMATIC REVIEW

Efficacy of Multi-Component Exercise-Based Injury Prevention Programs on Injury Risk Among Footballers of All Age Groups: A Systematic Review and Meta-analysis

Rilind Obërtinca[1,3] · Ilir Hoxha[2,4,5] · Rina Meha[1,4] · Arber Lama[4,5,6] · Altina Bimbashi[4] · Dorentina Kuqi[4] · Bujar Shabani[4,6] · Tim Meyer[1] · Karen aus der Fünten[1]

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Abstract

Background Playing football is associated with a high risk of injury. Injury prevention is a priority as injuries not only negatively impact health but also potentially performance. Various multi-component exercise-based injury prevention programs for football players have been examined in studies.

Objective We aimed to investigate the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups in comparison to a control group.

Methods We conducted a systematic review and meta-analysis of randomized and cluster-randomized controlled trials. CINAHL, Cochrane, PubMed, Scopus, and Web of Science databases were searched from inception to June 2022. The following inclusion criteria were used for studies to determine their eligibility: they (1) include football (soccer) players; (2) investigate the preventive effect of multi-component exercise-based injury prevention programs in football; (3) contain original data from a randomized or cluster-randomized trial; and (4) investigate football injuries as the outcome. The risk of bias and quality of evidence were assessed using the Cochrane Risk of Bias Tool and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE), respectively. The outcome measures were the risk ratio (RR) between the intervention and the control group for the overall number of injuries and body region-specific, contact, and non-contact injuries sustained during the study period in training and match play.

Results Fifteen randomized and cluster-randomized controlled trials with 22,177 players, 5080 injuries, and 1,587,327 exposure hours fulfilled the inclusion criteria and reported the required outcome measures. The point estimate (RR) for the overall number of injuries was 0.71 (95% confidence interval [CI] 0.59–0.85; 95% prediction interval [PI] 0.38–1.32) with very low-quality evidence. The point estimate (RR) for lower limb injuries was 0.82 (95% CI 0.71–0.94; 95% PI 0.58–1.15) with moderate-quality evidence; for hip/groin injuries, the RR was 0.56 (95% CI 0.30–1.05; 95% PI 0.00–102.92) with low-quality evidence; for knee injuries, the RR was 0.69 (95% CI 0.52–0.90; 95% PI 0.31–1.50) with low-quality evidence; for ankle injuries, the RR was 0.73 (95% CI 0.55–0.96; 95% PI 0.36–1.46) with moderate-quality evidence; and for hamstring injuries, the RR was 0.83 (95% CI 0.50–1.37) with low-quality evidence. The point estimate (RR) for contact injuries was 0.70 (95% CI 0.56–0.88; 95% PI 0.40–1.24) with moderate-quality evidence, while for non-contact injuries, the RR was 0.78 (95% CI 0.55–1.10; 95% PI 0.25–2.47) with low-quality evidence.

Conclusions This systematic review and meta-analysis indicated that the treatment effect associated with the use of multi-component exercise-based injury prevention programs in football is uncertain and inconclusive. In addition, the majority of the results are based on low-quality evidence. Therefore, future high-quality trials are needed to provide more reliable evidence.

Clinical Trial Registration PROSPERO CRD42020221772.

Extended author information available on the last page of the article

Key Points

The present meta-analysis is the first to use prediction intervals in the interpretation of results derived from trials assessing the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups.

This study revealed that the evidence for meaningful effects of exercise-based injury prevention programs remains inconclusive at best.

The quality of evidence is a major issue in existing studies; therefore, these findings call for future high-quality trials to provide more reliable evidence.

1 Background

The overall injury incidence in professional male football players is between 5.9 [1] and 9.6 [2] injuries/1000 football hours. In amateur and veteran football, reported incidences are even higher and reach 9.6 [2] to 12.5 [3] and 12.4 [4] injuries/1000 football hours, respectively. There are hardly any data regarding players under the age of 11 years [5]. A professional football team with 25 players has approximately 50 injuries per season [6], and youth elite teams about 30 [7]. Many efforts have been made in recent years to reduce these numbers. Various injury prevention programs for football players of both sexes and various age groups have been established. Some of them target specific injuries, for example, Prevent injury and Enhance Performance [8] and HarmoKnee [9], target knee injuries. Others take a more general approach, trying to prevent non-contact lower extremity injuries in general for example, FIFA® 11 [10], FIFA® 11+ [11], and the Neuromuscular training program [12]. 11+Kids [13] aims to prevent football injuries by increasing children's fundamental and sport-specific motor skills.

Previous systematic reviews and meta-analyses have evaluated the efficacy of either specific programs (e.g., FIFA 11 and 11+) [14, 15] or the effect of various programs on specific injuries (e.g., non-contact injuries) [16]. However, recognizing the differences between programs regarding the content, the different age groups targeted, and the different results reported compared to each other, a comprehensive meta-analysis of pooled results across the studies will produce a more comprehensive result. To date, no meta-analysis is available that has evaluated the efficacy of all multi-component exercise-based injury prevention programs in reducing the overall number of injuries as well as body region-specific injuries, and considering footballers of all age groups (children, youth, senior, and veteran). Additionally, contact-related injuries represent 50% of overall injuries in professional football [17]. Previous research has not investigated the impact of the programs on preventing these injuries. Providing information about the age-specific efficacy and estimating the potential of these programs on contact-related injuries may guide future evidence-based directions regarding the implementation and development of new interventions. Finally, providing only confidence intervals (CIs) might not be the best way forward. A recent meta-analysis examined the effect of the Nordic hamstring exercise [18]. The authors strongly recommended providing the prediction intervals (PIs) in addition to CIs. This is in line with authors promoting the use of PIs in the interpretation of results from a random-effects meta-analysis of trials assessing treatment effects [19]. Therefore, and for the first time, this meta-analysis reports the PIs in addition to the CIs. The aim of this meta-analysis was to investigate the efficacy of multi-component exercise-based injury prevention programs in reducing injuries of different types among footballers of all age groups.

2 Methods

2.1 Protocol and Registration

We report this systematic review in accordance with the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [20]. The study was registered at PROSPERO (ID: CRD42020221772).

2.2 Study Eligibility Criteria

In the present study, we included all controlled, multi-component exercise-based injury prevention programs containing at least two or more exercises. Players of the intervention group performed these programs during their training sessions in addition to their usual training and were compared to a control group. Criteria for study inclusion were: (1) include football (soccer) players; (2) investigate the preventive effect of multi-component exercise-based injury prevention programs in football; (3) contain original data from a randomized or cluster-randomized trial; and (4) investigate football injuries as the outcome. Studies were excluded from the meta-analysis if they were: (1) studies with a single exercise intervention; (2) studies with a primary target on performance or other physical measurements than injuries; (3) studies using protective equipment (e.g., bracing) as part of the intervention; and (4) studies published in a language other than English.

2.3 Sources and Study Selection

Possible studies were identified using a systematic search process. First, we searched the following databases CINAHL, Cochrane, PubMed, Scopus, and Web of Science from the earliest record to June 2022, with the following search strategy: (injury prevention OR warm-up program OR neuromuscular program OR f-marc OR 11 +) AND (football OR soccer). The reference lists of the studies recovered were hand searched to identify potentially eligible studies missed by electronic searches. Two reviewers independently (AB, DK) performed the selection of studies based on the title and abstract provided by the bibliographic databases. The full-text evaluation followed on those selected studies from the first selection step. A third reviewer (RO) was responsible for resolving any discrepancies in the selection process.

2.4 Data Extraction and Administration

For each eligible study, four reviewers (RM, AB, DK, AL) extracted data independently using a standardized data extraction form [14]. One section was added (type of injuries: contact or non-contact) to the extraction form for an additional analysis that we performed regarding the effect on contact versus non-contact injuries. We extracted data on the studies' basic information, design, participants, intervention characteristics, and outcome measures. Thereafter, the reviewers compared the extracted data for consistency. Reviewers resolved discrepancies by discussion and, when necessary, a fifth party (RO) was involved. Final decisions were made based on a majority vote. Primary outcome results from individual studies were extracted and collated in Excel 365 (Microsoft Corporation, Redmond, WA, USA).

2.5 Quality Assessment

The risk of bias was assessed for each included trial according to the recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions [21]. The following items were considered: allocation sequence generation, concealment of allocation, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. As it is impossible to blind the participants to the intervention, we removed the item "blinding of participants and investigators". Each bias domain was judged as at low or high risk of bias according to its possible effect on the results of the study. When the possible effect was unknown or insufficient detail was reported, we judged it as unclear. The risk of bias was examined independently by two reviewers (RO, BSH). Discrepancies were resolved by consensus. The overall quality of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE). This method assesses the strength of evidence derived from systematic reviews [22]. In the GRADE system, randomized controlled trials (RCTs) begin as high-quality evidence [23]. Subsequently, the evidence is downgraded by one level for each of the following domains considered: (1) risk of bias (downgraded by one level if the trials scored an overall high risk of bias on the Cochrane Collaboration Risk of Bias Tool); (2) inconsistency (downgraded by one level if statistical heterogeneity between studies was $I^2 > 50\%$); (3) indirectness (downgraded by one level if the meta-analysis included participants with heterogeneous characteristics with regard to sex, age, and level of sport); (4) imprecision (downgraded by one level if the upper and lower CIs had a > 0.5 difference); and (5) publication bias (assessed with a visual inspection of a funnel plot and two-tailed Egger's test if more than ten studies were included in the meta-analysis). Evidence obtained was categorized into four levels of evidence quality: high, moderate, low, and very low [24] (Table 1).

2.6 Outcome Measures

The primary outcome was the risk ratio (RR) for the overall number of injuries. Body region-specific injury RRs for the lower limb, hamstring, hip/groin, knee, and ankle were secondary outcomes. Additionally, the overall number and the region-specific injury RRs were assessed for a non-contact versus contact induced cause. All injuries occurring in official training and match play during the respective study period were included.

2.7 Synthesis of Results

If studies did not report RR estimates, we converted them to RRs as far as possible [25, 26]. Out of the 15 included studies, six studies did not perform cluster adjustments. They also did not provide information on the intra-cluster correlation coefficient or other data that would allow for calculating the design effect or inflation factor (as recommended by the Cochrane Handbook for Systematic Review of Interventions) [27]. Hence, we performed a cluster adjustment by increasing variance by 30% for effect estimates of studies with no adjustment for the cluster effect [28]. We performed a meta-analysis of RRs and their 95% CIs using the DerSimonian and Laird random-effects method [29]. A random-effects meta-analysis assumes that the true treatment effect varies among studies. The DerSimonian and Laird method does not make any assumptions about the distribution of the random effects [30]. In addition to the presentation of overall effect estimates and 95% CIs, we also calculated 95% PIs.

Table 1 Grades of recommendation, assessment, development and evaluation (GRADE) quality of evidence

Meta-analyses	Number of RCT's	Risk of bias[a]	Inconsistency[b]	Indirectness[c]	Imprecision[d]	Publication bias[e]	Effect RR (95% CI)	GRADE quality
Overall injuries All studies	11	◯	◯	⊕	⊕	◯	0.71 (0.59 to 0.85)	⊕⊕◯◯◯ Very low
Lower limb injuries All studies	9	◯	⊕	⊕	⊕	-	0.82 (0.71 to 0.94)	⊕⊕⊕◯ Moderate
Hip/groin injuries All studies	3	◯	⊕	⊕	◯	-	0.56 (0.30 to 1.05)	⊕⊕◯◯ Low
Hamstring injuries All studies	2	◯	⊕	⊕	◯	-	0.83 (0.50 to 1.37)	⊕⊕◯◯ Low
Knee injuries All studies	11	◯	◯	⊕	⊕	⊕	0.69 (0.52 to 0.90)	⊕⊕⊕◯◯ Low
Ankle injuries All studies	7	◯	⊕	⊕	⊕	-	0.73 (0.55 to 0.96)	⊕⊕⊕◯ Moderate
Contact injuries All studies	6	◯	⊕	⊕	⊕	-	0.68 (0.55 to 0.84)	⊕⊕⊕◯ Moderate
Non-Contact injuries All studies	6	◯	◯	⊕	⊕	-	0.73 (0.53 to 1.01)	⊕⊕◯◯ Low

[a] Downgraded if the trials scored an overall high risk of bias on the Cochrane Collaboration Risk of Bias Tool.

[b] Downgraded if statistical heterogeneity between studies was ($I^2 > 50\%$).

[c] Downgraded by one level if meta-analysis included participants with heterogeneous characteristics.

[d] Downgraded if the upper and lower CIs had >0.5 difference.

[e] Assessed with visual inspection of the funnel plot and two-tailed Egger test (if >10 studies were included in the meta-analysis).

CI confidence interval, *RCT* randomized controlled trial, *RR* risk ratio

They enable the examination of treatment effects within an individual study setting, as this can differ from the average effect [19]. Heterogeneity was assessed using I^2, τ^2, and Q value (χ^2 test for heterogeneity). We interpreted I^2 values according to guidelines by Higgins and Green, a low heterogeneity for I^2 values between 25 and 50%, a moderate *f* heterogeneity or 50–75%, and a high heterogeneity for ≥ 75% [27]. A small study effect was investigated using Egger's test for a meta-analysis with ten or more studies [31]. Statistical analysis was carried out using STATA 17 BE (Stata Corporation, College Station, TX, USA).

3 Results

3.1 Literature Identification

The initial database search identified 7954 studies. Following the removal of duplicates ($n = 4986$), 2968 studies remained. After screening the titles and abstracts, 69 full-text articles were left. A further 54 studies had to be excluded as they did not present data on injuries, included non-football players, or were neither cluster RCTs nor RCTs. Finally, 15 articles were included in the meta-analysis (Fig. 1).

3.2 Demographic and Study Characteristics

Eight trials stemmed from Europe [4, 9–11, 13, 32–34]. Two trials were conducted in the USA [8, 35]. One trial was conducted in one each of the following countries: Canada [12], Australia [36], Rwanda [37], Nigeria [38], and Iran [39]. The overall number of participants was 22,177 including both sexes. Participants were registered football players in one of the following age groups: children (7–14 years), youth (12–19 years), senior, and veteran (> 32 years). The number of participants ranged from 265 [4] to 4564 participants [9]. A total of 5080 injuries and 1,587,327 h of exposure were included. The study period lasted between 12 weeks [8] and 9 months [4, 13, 39, 33]. All interventions were applied at least twice a week in the training sessions. The control groups performed their usual warm-up exercises and/or training routines. One study required an additional home-based stretching program [12]. Nine studies used a FIFA® warm-up program of the FIFA® 11, the FIFA® 11 +, or the 11 + Kids [4, 10, 11, 13, 33, 35, 37–39]. Two studies used Neuromuscular Training programs [12, 32], and one study each used the Neuromuscular Control Program [36], the Knäkontroll program [9], the Prevention Injury and Enhance Performance program [8], and the Bounding Exercise Program [34] (Table 2).

3.3 Risk of Bias

Seven (46%) studies had a high risk of bias in two or more domains. The domain "other bias" was the most frequent cause for a high risk of bias within the studies (46%), with seven studies neither reporting an intention-to-treat analysis nor an adjustment for clustering (Fig. 1 and Table 1 of the Electronic Supplementary Material [ESM]).

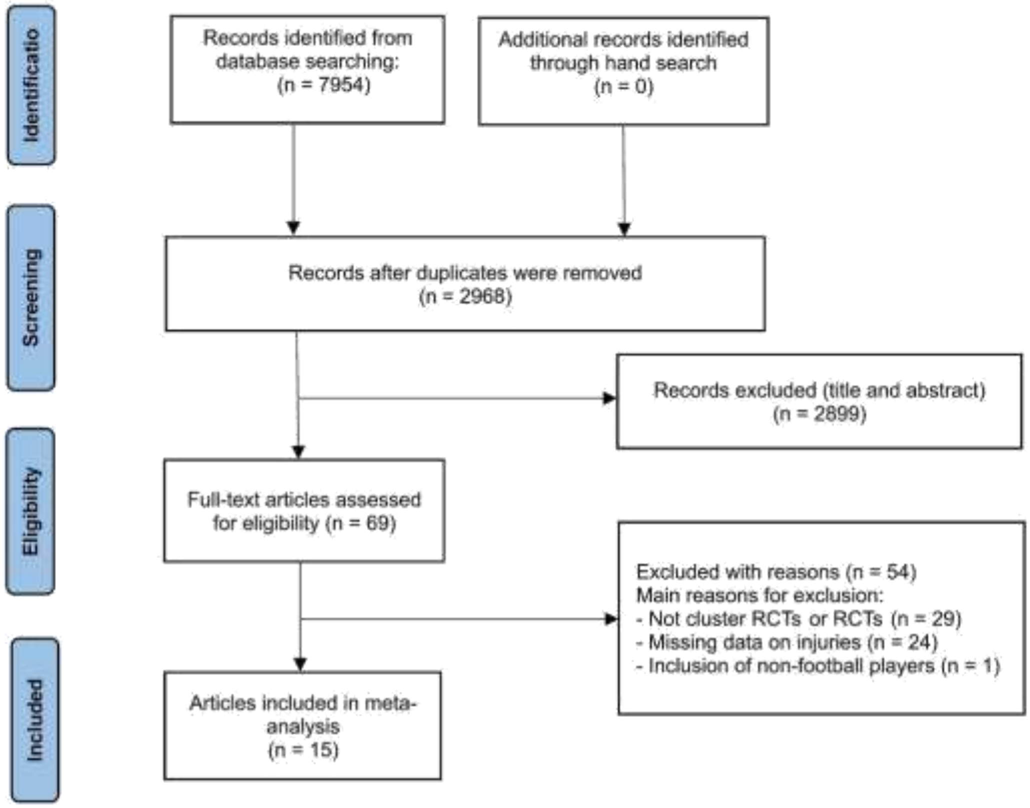

Fig. 1 Flow chart of the included studies. *RCTs* randomized controlled trials

3.4 Meta-Analysis Results

3.4.1 Overall, Body Region, Contact, and Non-Contact-Related Injuries

For the primary outcome analysis, i.e., the overall injury risk, the pooled results showed a point estimate (RR) of 0.71 (95% CI 0.59–0.85; 95% PI 0.38–1.32; $I^2=80.5\%$; $\tau^2=0.067$; $p<0.001$). The width of the 95% PI suggests that the effect in future similar studies lies between 0.38 and 1.32 (Fig. 2). In practical terms, the effect may vary from being very protective to an increased risk of injury. The level of evidence was rated as very low (downgraded one level because of a risk of bias, one level because of inconsistency, and one level because of publication bias) (Table 1).

Regarding the secondary outcome analyses, i.e., the body region-specific injury risk (Fig. 2), the point estimate (RR) for the lower limb injuries was 0.82 (95% CI 0.71–0.94; 95% PI 0.58–1.15; $I^2=45.3\%$; $\tau^2=0.016$; $p=0.067$) with moderate-level evidence (downgraded one level because of a risk of bias). For knee injuries, the RR was 0.69 (95% CI 0.52–0.90; 95% PI 0.31–1.50) with low-level evidence (downgraded one level because of a risk of bias and one level because of inconsistency). For hip/groin injuries, the RR was 0.56 (95% CI 0.30–1.05; 95% PI 0.00–102.92) with low-level evidence (downgraded one level because of a risk of bias and one level because of imprecision). For hamstring injuries, the RR was 0.83 (95% CI 0.50–1.37) with low-level evidence (downgraded one level because of a risk of bias and one level because of imprecision). With regard to ankle injuries, the RR was 0.73 (95% CI 0.55–0.96; 95% PI 0.36–1.46) with moderate-level evidence (downgraded one level because of a risk of bias). For each calculation, the 95% PI was wider in comparison to the 95% CI.

The pooled results for non-contact injuries showed a point estimate (RR) of 0.78 (95% CI 0.55–1.10; 95% PI 0.25–2.47; $I^2=67.3\%$; $\tau^2=0.100$; $p=0.016$), with evidence rated as low level (downgraded one level because of a risk of bias and one level because of inconsistency). Additionally, the point estimate (RR) for contact injuries was 0.70 (95% CI 0.56–0.88; 95% PI 0.40–1.24 $I^2=29.2\%$; $\tau^2=0.018$; $p=0.227$), with moderate-level evidence (downgraded one level because of a risk of bias). The width of the 95% PI suggested that the effect may vary from being very protective

Table 2 Summary of included multi-component randomized controlled trials investigating the effect of injury prevention programs

Study	Intervention program	Population (age)	Follow-up	Outcome	Number of analysed (players)	Exposure time (h)	Number of injuries
Emery et al. 2010 [12]	Neuromuscular training program	Male and female youth (13–18 years)	20 weeks	Overall injuries	IG: 380 CG: 364	IG: 24 051 CG: 24 597	IG: 50 CG: 79
Finch et al. 2016 [36]	Neuromuscular control program	Male senior (18–30 years)	28 weeks	Overall injuries	IG: 679 CG: 885	IG: 12 790[a] CG: 15 537[a]	IG: 335 CG: 438
Gilchrist et al. 2008 [8]	PEP	Female senior, (19.88 years)[b]	12 weeks	Knee injuries	IG: 583 CG: 852	IG: 35 220 CG: 52 919	IG: 40[c] CG: 58[c]
Hammes et al. 2015 [4]	FIFA® 11+	Male veteran (≥32 years)	9 months	Overall injuries	IG: 146 CG:119	IG: 4 172 CG: 2 937	IG: 51 CG: 37
Hilska et al. 2021 [32]	Neuromuscular training	Male and female children (9–14 years)	20 weeks	Lower limb injuries	IG: 673 CG: 730	IG: 71 109 CG: 63 404	IG: 310[d] CG: 346[d]
Nuhu et al. 2021 [37]	FIFA® 11+	Male senior (IG: 19.9 years) (CG: 19.7 years))	7 months	Overall injuries	IG: 309 CG: 317	IG: 65 333 CG: 63 389	IG: 168 CG: 252
Owoeye et al. 2014 [38]	FIFA® 11+	Male youth (14–19 years)	6 months	Overall injuries	IG: 212 CG: 204	IG: 51 017 CG: 61 045	IG: 36 CG: 94
Rossler et al. 2018 [13]	11+Kids	Male and female children (7–13 years)	9 months	Overall injuries	IG: 2066 CG: 1829	IG: 140 716 CG: 152 033	IG: 139 CG: 235
Silvers-Granell et al. 2017 [35]	FIFA® 11+	Male senior (18–25 years)	5 months	Overall injuries	IG: 675 CG: 850	IG: 35 226 CG: 44 212	IG: 285 CG: 665
Soligard et al. 2008 [11]	FIFA® 11+	Female youth (13–17 years)	8 months	Overall injuries	IG: 1055 CG: 837	IG: 49 899 CG: 45 428	IG: 161 CG: 215
Steffen et al. 2008 [10]	FIFA® program 11	Female youth (13–17 years)	8 months	Overall injuries	IG: 1073 CG: 947	IG: 66 423 CG: 65 725	IG: 242 CG: 241
Walden et al. 2012 [9]	Knakontrol	Female youth (12–17 years)	7 months	ACL injuries	IG: 2479 CG: 2085	IG: 149 214 CG: 129 084	IG: 7[e] CG: 14[e]
Zarei et al. 2020 [39]	11+kids	Male children (7–14 years)	9 months	Overall injuries	IG: 443 CG: 519	IG: 31 934 CG: 32 113	IG: 30 CG: 60
Van de Beijsterveldt et al. 2012 [33]	FIFA® program 11	Male senior (18–40 years)	9 months	Overall injuries	IG: 233 CG: 233	IG: 21 605 CG: 22 647	IG: 207 CG: 220
Van de Hoef et al. 2019 [34]	BEP	Male senior (18–45 years)	39 weeks	Hamstring injuries	IG: 229 CG: 171	IG: 31 831 CG: 21 717	IG: 35[f] CG: 30[f]

ACL anterior cruciate ligament, *BEP* bounding exercise program, *CG* control group, *IG* intervention group, *N/A* Not applicable, *PEP* Prevent injury and Enhance Performance

[a]Match exposure only was reported

[b]Average age only was reported

[c]Knee injuries

[d]Lower limb injuries

[e]ACL injuries

[f]Hamstring injuries

to an increased risk of injury for both outcomes, i.e., non-contact injuries (95% PI 0.55–1.10) and contact injuries (95% PI 0.40–1.24) (Fig. 3).

3.4.2 Subgroup Analysis According to Sex

Regarding a distinction between male and female individuals, the point estimate (RR) for the overall number of injuries

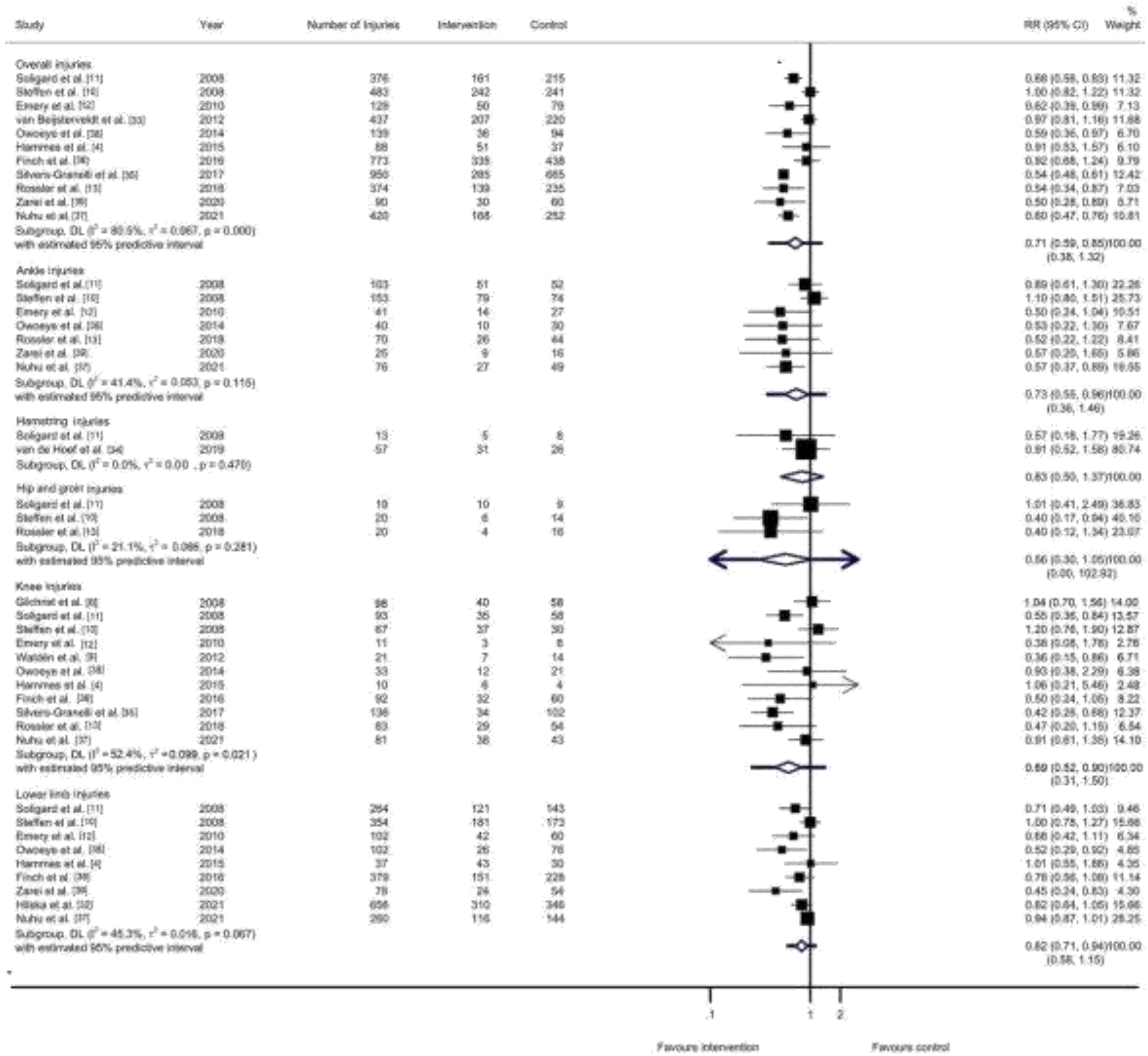

Fig. 2 Analysis of multi-component exercise-based injury prevention programs' effect on the overall and region-specific injury risk compared with control groups. I^2 *I* square, *p p* value, *RR* risk ratio, τ^2 tau square

in male football players was 0.70 (95% CI 0.55–0.90; $I^2=83.5\%$; $\tau^2=0.082$; $p<001$). In female football players, the point estimate (RR) was 0.82 (95% CI 0.57–1.20; $I^2=68.9\%$; $\tau^2=0.064$; $p=0.008$) (Fig. 4 of the ESM).

3.4.3 Subgroup Analysis According to Age Group

The point estimate (RR) for the overall number of injuries in children was 0.52 (95% CI 0.36–0.76; $I^2=0.0\%$; $\tau^2<0.001$; $p=0.841$), in youth, the RR was 0.74 (95% CI 0.56–0.97; $I^2=68.9\%$; $\tau^2=0.048$; $p=0.022$), in seniors, the RR was 0.73 (95% CI 0.53–1.01; $I^2=91.1\%$; $\tau^2=0.098$; $p<0.001$), and, in veterans, the RR was 0.91 (95% CI 0.53–1.57) (Fig. 4 of the ESM).

4 Discussion

4.1 Principal Findings

This systematic review and meta-analysis included 15 RCTs that assessed the effect of injury prevention programs on the overall and body region-specific injury risk in football players. Based on calculated PIs, their efficacy remains uncertain

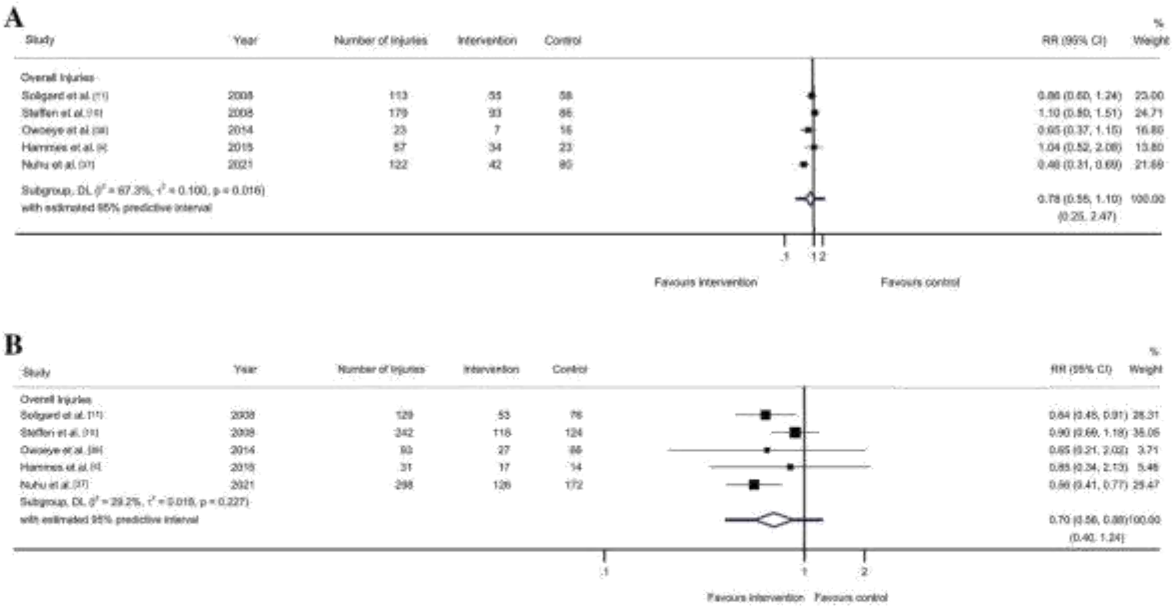

Fig. 3 Analysis of multi-component exercise-based injury prevention programs' effect on the overall non-contact (**a**) and contact (**b**) injury risk compared with control groups. I^2 I square, *p* *p* value, *RR* risk ratio, τ^2 tau square

and inconclusive regarding all primary and secondary outcomes. In addition, the majority of the results are based on low-quality evidence.

4.1.1 Comparison with Existing Literature on Injury Risk Reduction

Riley et al. [40] suggested that if a random-effects approach is used, the pooled result must be interpreted as the average intervention effect across studies, rather than the common effect. Previous meta-analyses have not reported PIs, which means, an appropriate comparison is not possible. Therefore, we can only compare our point estimates with those reported in the literature. In contrast with the currently available evidence [14–16, 41], our study included footballers of all age groups and skill levels (amateur and professional). The point estimate (RR) of 0.71 (95% CI 0.59–0.85) in the current analysis is at the lower end of those reported in previous systematic reviews, which reported an incidence rate ratio (IRR) of 0.73 (95% CI 0.59–0.91) [41], IRR of 0.75 (95% CI 0.57–0.98) [14], IRR of 0.77 (95% CI 0.64–0.91) [15], and IRR of 0.77 (95% CI 0.61–0.97) [16]. This was to be expected as we also included interventions in children, which showed a substantially higher injury reduction of 48% [13] and 50% [39] compared with older players. This effect was somewhat counterbalanced by the reduced effect of the programs among veterans, which was only 9%. However, the relative weight of the studies with children was higher (higher in the number of studies and participants). A previous meta-analysis [14] investigated the effect of the FIFA® exercise-based injury prevention programs on specific body regions. The observed efficacy on hamstring (RR 0.83 vs IRR 0.40), knee (RR 0.69 vs IRR 0.52), and ankle injuries (RR 0.73 vs IRR 0.68) was lower in our study, but comparable for hip/groin injuries (RR 0.56 vs IRR 0.59). A likely explanation for the differing results between the reviews is that we included a higher number of studies that examined different types of programs in the analysis. An additional explanation could be the inclusion of studies with children because injury patterns vary with age [42]. The most obvious difference from other studies was regarding hamstring injuries. The results may be expected as we did not include trials investigating the Nordic Hamstring as a single component exercise, which has been shown to be very effective for preventing hamstring injuries [43]. Moreover, in comparison to Thorborg et al. [14], we included the Bounding Exercise Program [34], which showed very little effect in reducing these injuries.

4.1.2 Effectiveness of Injury Prevention Programs on Contact Versus Non-contact Injuries

For the first time, this study investigated the effect of multi-component exercise-based injury prevention programs not only on non-contact injuries but also on contact-related injuries. The point estimate (RR) for contact injuries was 0.70 (95% CI 0.56–0.88). Surprisingly, the estimated risk reduction was higher than for non-contact injuries for which the vast majority of programs are designed. Most programs include strength exercises that mostly focus on core stability. Furthermore, plyometrics (hopping, jumping, and landing) are often part of the programs. They have the potential to improve lower leg strength, functional leg stability, and balance, thus improving the ability to absorb external forces, for example, induced by contact. The 11 + Kids [13] program also includes one exercise specifically on correct falling techniques. The point estimate (RR) for non-contact injuries in the current study was 0.78, in line with a previous study that reported a RR of 0.77 [16].

4.1.3 Effectiveness of Injury Prevention Programs Across Sexes and Age Groups

The subgroup analysis showed a point estimate (RR) of 0.70 in male football players. These results mimic the data of the Al Attar et al. study [15]. However, the estimated effect is slightly lower than data reported by Lemes et al. [16] showing a point estimate (RR) of 0.68.

Regarding female individuals, the pooled results showed a point estimate (RR) of 0.82. This result falls within the range of results reported by studies with similar inclusion criteria [15, 16]. However, the meta-analysis with the largest estimated effect [41] included RCTs that used various injury prevention strategies. In addition to physical exercises, they included studies that used braces and education as a method for prevention. Furthermore, they included studies with participants of varying backgrounds and sports (i.e., middle and high school non-footballer athletes). These dissimilarities might have caused these considerable differences. In contrast, small differences compared with other reviews [15, 16] may reflect the diversity of interventions, i.e., the inclusion of single-component exercise-based injury prevention programs.

The subgroup analysis for age groups showed a point estimate (RR) of 0.52 in children, a RR of 0.74 in youth, 0.73 in seniors, and 0.91 in veteran football players. The point estimate in youth and seniors is homogeneous with the current available evidence [14, 41]. The low point estimate found in children may be expected by the fact that there is rarely any prior use of preventative measures at all; therefore, using the program is likely to evoke the biggest benefit. Only one trial [4] assessed the effects of injury prevention programs in veteran football players. The comparably small effect in this population is likely owing to the infrequent application of the program (only once a week) as well as relatively low compliance.

4.2 Factors to Take into Account When Assessing PIs

In the current analysis, we calculated the PIs for the main investigated outcomes. Prediction intervals were wider in comparison to confidence intervals. Based on this evidence, there is a lack of compelling data to affirm the certainty of preventive effects from multi-component exercise-based injury prevention programs. However, for our meta-analysis, we have to take into account that the use of PIs has its shortcomings. IntHout et al. [19] mentioned that they show a wider range compared with CIs when there is any heterogeneity. Our main outcome provided an $I^2 = 80.5\%$, which should be interpreted as high heterogeneity according to the Cochrane Handbook for Systematic Reviews of Interventions [27]. In addition, Riley et al. [40] stated that a PI will be most appropriate when the studies included in the meta-analysis have a low risk of bias. However, the majority of studies in our analysis had a high risk of bias. Therefore, these shortcomings would have affected the use of PIs in our meta-analysis.

4.3 Strengths and Limitations

To the best of our knowledge, this review is the first to analyze the efficacy of multi-component exercise-based injury prevention programs among footballers of all age groups. One strength of this systematic review is that it included multiple analyses. It investigated the risk reduction for the overall number of injuries as well as of body region-specific, contact, and non-contact injuries. Subgroup analyses for age and sex were also performed. Additionally, the PIs for the main outcomes were calculated. A further strength is the large number of participants (22,177), injuries (5080), and exposure hours (1,587,327 h) included in comparison with other reviews [14–16]. Furthermore, we followed best practice by including only randomized trials and cluster-RCTs, using a risk of bias assessment and grading the quality of evidence.

However, this review also has some limitations, mainly that > 50% of the reported effects were based on studies with a very low or low level of evidence. The main outcome variable provided high heterogeneity among the studies ($I^2 = 80.5\%$). The lack of information about compliance with the prevention program in many studies is another limitation of this review. Furthermore, there was missing information on content and compliance with the usual warm-ups/training routines of the control groups. Another limitation is the high risk of bias, especially from the "other bias" domain, with seven studies failing to report the use of an intention-to-treat analysis and of an adjustment for clustering. Finally, two deviations (lack of a compliance analysis and the modification of literature databases) from the original study protocol have to be mentioned as limitations of this review.

4.4 Differences Between the Protocol and Review

Owing to the lack of respective information provided in the studies, a compliance analysis was impossible. We contacted the corresponding authors to provide us with these data, but within the set time of 2 weeks, we only received information on one of the studies. Our planned bibliographic databases for literature identification were modified during the study implementation. Because of the lack of access, we did not search in EMBASE and SPORTDiscus. However, we additionally searched in the originally unplanned database Scopus. In addition, to empower the review, although it was not registered in the protocol, we assessed the quality of evidence using the GRADE approach and calculated the PIs for the main outcomes.

4.5 Recommendations for Future Studies

Based on the data obtained, we recommend future high-quality trials to investigate the efficacy of multi-component exercise-based injury prevention programs. In upcoming studies, data on compliance and the content of the training of the control groups should be included. Adjustment for clustering and more extensive reporting of outcomes should be emphasized. In addition, it appears important to create new injury prevention programs that reflect the development and changes in football training. This should include increasing their attractiveness to promote compliance (also outside of study settings), which appears crucial to reduce injury risk. Currently, a large number of different exercises are included because it is unknown which exercises (or which combination of them) are most effective in general or in relation to specific injuries. Tailoring the exercises would potentially mean fewer injuries and more efficiency.

5 Conclusions

This meta-analysis indicated that evidence for the meaningful effects of multi-component exercise-based injury prevention programs in football remains inconclusive at best. This statement is based on PIs that were wider than the frequently employed CIs, with a range from very protective effects to an increased injury risk. In addition, the quality of evidence is a major issue in existing studies. These findings call for future high-quality trials to provide more reliable evidence regarding the efficacy of injury prevention programs in football.

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Declarations

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Conflicts of interest/competing interests Rilind Obërtinca, Ilir Hoxha, Rina Meha, Arber Lama, Altina Bimbashi, Dorentina Kuqi, Bujar Shabani, Tim Meyer, and Karen aus der Fünten have no conflicts of interest that are directly relevant to the content of this article.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Availability of data and material The datasets generated and/or analyzed during the study implementation are available from the corresponding author upon request.

Code availability Not applicable.

Authors' contributions RO, IH, and KadF conceived and designed the study. RO, IH, RM, AL, AB, DK, and BSH conducted the search, study selection, data extraction, and quality appraisal. IH analyzed the data. RO, IH, and KadF contributed to the interpretation of the data. RO drafted the manuscript with input from KadF and TM. All authors have read and approved the final manuscript.

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Authors and Affiliations

Rilind Obërtinca[1,3] · Ilir Hoxha[2,4,5] · Rina Meha[1,4] · Arber Lama[4,5,6] · Altina Bimbashi[4] · Dorentina Kuqi[4] · Bujar Shabani[4,6] · Tim Meyer[1] · Karen aus der Fünten[1]

✉ Rilind Obërtinca
rilind.obertinca1@gmail.com

1 Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken Campus, Building B8 2, 66123 Saarbrücken, Germany

2 Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, NH, USA

3 Department of Physiotherapy, University of Gjakova "Fehmi Agani", Gjakova, Kosovo

4 Research Unit, Heimerer College, Pristina, Kosovo

5 Evidence Synthesis Group, Pristina, Kosovo

6 University Clinical Center of Kosovo, Pristina, Kosovo

Efficacy of a new injury prevention programme (FUNBALL) in young male football (soccer) players: a cluster-randomised controlled trial

Rilind Obërtinca [1,2] Rina Meha,[1] Ilir Hoxha,[3,4] Bujar Shabani,[5,6] Tim Meyer [1] Karen aus der Fünten[1]

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[1]Institute of Sports and Preventive Medicine, Saarland University, Saarbrucken, Germany
[2]Department of Physiotherapy, University 'Fehmi Agani' in Gjakova, Gjakova, Kosovo
[3]The Dartmouth Institute for Health Policy and Clinical Practice, Geisel School of Medicine at Dartmouth, Lebanon, NH, USA
[4]Evidence Synthesis Group, Prishtina, Kosovo
[5]Faculty of Medicine, University of Prishtina, Prishtina, Kosovo
[6]Université Claude Bernard, Lyon, France

Correspondence to
Rilind Obërtinca, Institute of Sports and Preventive Medicine, Saarland University, Saarbrucken, 66123, Germany; riob00001@stud.uni-saarland.de

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ABSTRACT

Objectives To evaluate the efficacy of a new multicomponent, exercise-based injury prevention programme in football players 13–19 years old.

Methods Two-arm cluster-randomised controlled trial with clubs as the unit of randomisation. 55 football teams from Kosovo of the under 15, under 17 and under 19 age groups were randomly assigned to the intervention (INT; 28 teams) or the control group (CON; 27 teams) and were followed for one football season (August 2021–May 2022). The INT group performed the 'FUNBALL' programme after their usual warm-up at least twice per week, while the CON group followed their usual training routine. The primary outcome measure was the overall number of football-related injuries. Secondary outcomes were region-specific injuries of the lower limbs (hip/groin, thigh, knee, lower leg, ankle and foot) and injury severity.

Results 319 injuries occurred, 132 in the INT and 187 in the CON group. The INT group used the 'FUNBALL' programme in 72.2% of all training sessions, on average 2.2 times per week. There was a significantly lower incidence in the INT group regarding the overall number of injuries (incidence rate ratio (IRR) 0.69, 95% CI 0.55 to 0.87), the number of thigh injuries (IRR 0.62, 95% CI 0.39 to 0.98), of moderate (time loss between 7 and 28 days) (IRR 0.65, 95% CI 0.44 to 0.97) and of severe injuries (time loss >28 days) (IRR 0.51, 95% CI 0.28 to 0.91).

Conclusion The 'FUNBALL' programme reduced the incidence of football-related injuries among male adolescent football players, and its regular use for injury prevention in this population is recommended.

Trial registration number NCT05137015.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Youth football (soccer) is associated with a significant injury risk.
⇒ Various multicomponent exercise-based injury prevention programmes may reduce the risk of football-related injuries, but evidence is conflicting. Implementation of and adherence to these programmes can be challenging.

WHAT THIS STUDY ADDS

⇒ The 'FUNBALL' programme is an effective intervention used after the usual warm-up which lowers the injury incidence in male young football players.
⇒ The overall injury incidence was lowered by one-third when the 'FUNBALL' programme was applied for one season.
⇒ Preventive benefits were also found for thigh injuries, and for moderate and severe time-loss injuries.
⇒ The positive effect on injury burden led to better player availability.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Male adolescent football players should be encouraged to perform the 'FUNBALL' programme at least twice per week to induce maximal benefits.
⇒ More research is needed on the efficacy of the 'FUNBALL' programme in other age groups (senior and veteran players) as well as in female football players.
⇒ The 'FUNBALL' programme is more football specific compared with existing injury prevention programmes. Future studies should explore whether this aspect improves compliance and adherence compared with previous programmes.

INTRODUCTION

Youth football (soccer) is associated with a significant injury risk. The overall injury incidence in youth male football players has been reported between 2.4 and 12.0 injuries per 1000 football hours.[1 2] The majority of injuries concern the lower extremity,[1–4] especially the thigh region.[1 3–5] Severe injuries accounted for 21–37% of all injuries,[1 3] or 0.78 injuries per 1000 hours.[6] This aligns with injury locations and injury severity reported in adult professional football players.[6–8]

With the aim to reduce the number of football-related injuries, many exercise-based injury prevention programmes (IPPs) have been established. Some of them targeted specific injuries, for example, adductor,[9] hamstring[10 11] and knee injuries.[12–14] Others aimed to reduce the overall number of lower limb injuries.[15–18] In the above-mentioned cluster-randomised controlled trials (cluster-RCTs), the highest efficacy reported was a 77% reduction in injury rates.[14] Several meta-analyses supported the efficacy of IPPs.[19–21] A more cautious interpretation of their efficacy emerged recently when other meta-analyses included the calculation of prediction intervals.[22 23] Despite available evidence of their efficacy,[9–14 16–18 24–26] and the importance of good compliance for injury reduction,[27–29] many studies

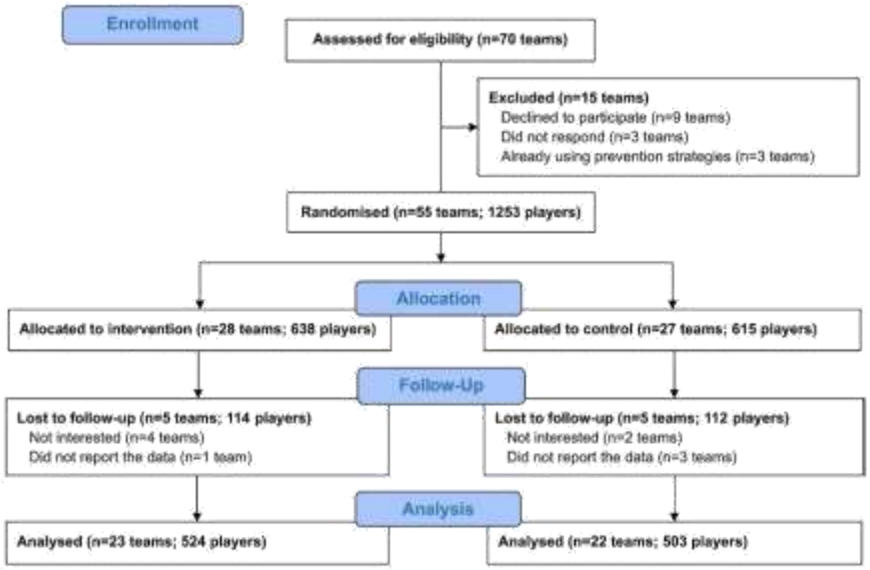

Figure 1 Consolidated Standards of Reporting Trials flow diagram of teams and players through trial.

highlighted a low programme compliance.[15 30 31] Efforts have been made to optimise strategies for increasing compliance and adherence.[32 33] Nonetheless, achieving broad-scale effectiveness of IPPs remains challenging.[34–37] The main perceived barriers to low compliance and adherence include time constraints, physical complaints (eg, fatigue and soreness) caused by exercises, lack of awareness and knowledge about the programmes' execution, and low motivation due to the absence of football-specific activities within the IPPs.[29 32]

We developed a multicomponent exercise-based IPP specifically targeting youth football players. The intention was to use as many football-specific elements as possible, based on the assumption that they increase motivation and compliance. Exercise categories were based on scientific evidence that has previously shown good efficacy in injury prevention in football. By means of a cluster-RCT, we aimed to evaluate the efficacy of the 'FUNBALL' programme to reduce injuries in male football players 13–19 years old.

METHODS

Study design and participants

The design of the study was a two-arm, cluster-RCT. It was chosen to reduce contamination bias within clubs. The study is reported according to the Consolidated Standards of Reporting Trials statement for cluster-randomised trials.[38] The study protocol was registered within ClinicalTrials.gov (NCT05137015).

At the beginning of 2020, 21 football clubs (with 70 teams in total) from different regions in Kosovo that fulfilled all inclusion criteria were invited to participate in our study, with their under 15s, under 17s and under 19s male teams (figure 1). All teams participated either in the Super League and/or Regional Leagues, organised by the Football Federation of Kosovo. To be included, teams had to: (1) be officially registered in the above-named football association, (2) train at least twice per week and (3) participate in regular matches of the above-named leagues. We excluded clubs that were already using a structured IPP. All the clubs that enrolled for the study were randomised either into the intervention or the control group. All teams from one club were randomised into the same treatment arm. Computer-generated randomisation stratified by league level (Super League or Regional League) was performed. The stratification was chosen to account for possible differences in competition level. The randomisation was performed by one researcher (RM), who was blinded to the identities of the clubs and who was not involved in the intervention.

Intervention

The intervention consisted of six **fun**damental exercise categories with the intention of preventing foot**ball**-related injuries, hence the abbreviation 'FUNBALL'. In addition, the programme contained one optional game. The following mandatory exercise categories were included: (1) balance, (2) core stability, (3) hamstring muscles eccentrics, (4) gluteal muscle activation, (5) plyometrics and (6) running/sprinting. The optional category (7) 'games' (three games included) reflected the intention to increase the attractiveness of the programme (table 1). Each mandatory category contained two different exercises to offer more variability. The coach was free to decide which of the two to choose for each training session. All exercises were organised in five or six progressive levels with increasing physical and cognitive difficulty, and were required to be performed in order (from 1 to 5/6). The exercises started on the first level and moved to the next one when exercises were executed with a proper technique as assessed by the coach. The programme took about 15–20 min to complete after familiarisation.

Based on the latest evidence regarding the challenge of long-term adherence,[34 35] and in accordance with what the implementation science has proposed in relation to IPP development,[33 35] it was decided among the coauthors who were involved in the development of the programme (RO, RM, TM and KadF) to include a football coach within the team for the development and refinement of the intervention. This with the intention to secure the end users' perspective throughout the whole process. The coach was not part of any team later included in the study, nor in the piloting or intervention period. In addition, a psychologist provided input for the neurocognitive demands of the programme. Prior to its implementation, the programme was piloted on two football teams. One exercise was replaced with

Table 1 Multicomponent exercise-based programme 'FUNBALL' used to prevent injuries in young football players

Exercises	Repetitions/duration	Number of levels
Balance		
a. Single-leg stance	2 sets×30s (on each leg)	6
b. Y-balance	3 sets×6–8 repetitions (on each leg)	6
Core stability		
a. Plank and side plank	2 sets×20–40s (on each position)	6
b. Straight arm plank	2 sets×8–12 repetitions	6
Hamstring muscles eccentrics		
a. Nordic hamstring	1–2 sets×3–10 repetitions	5
b. Hamstring walk-outs	2–3 sets×30s	5
Gluteal muscle activation		
a. Head, shoulder, hip, knee, ankle	2 sets×6–10 repetitions	6
b. Squat lunges	2–3 sets×8–12 repetitions	6
Plyometric		
a. Forward jumps	4 sets×3 jumps	5
b. Skater jumps	4 repetitions (2 on each leg)	5
Running/sprinting		
a. Diagonal running/sprinting	3 repetitions	6
b. Forward running/sprinting	3 repetitions	6
Games		
a. Tic-tac-toe	3–5 games	n.a.
b. Header game	4–5 repetitions for each player	n.a.
c. Dribbling game	3 games	n.a.

n.a., not applicable.

another after the suggestions from the coaches as it was reported as too time-consuming. The pilot teams were not invited to participate in the study. To further address the compliance issue, we tried to make the programme as football specific as possible. We introduced exercises requiring competition between the players, offered two variations for each exercise category and cognitive challenges in the majority of exercises. Furthermore, the ball was included as often as possible. Previous IPPs replaced the warm-up.[15 16 18] However, coaches may take this as a restriction, which may affect the long-term compliance. Therefore, we designed the 'FUNBALL' programme to be used after the usual warm-up. In order to maintain the benefits of warm-up, most of the 'FUNBALL' exercises were of relatively high intensity, especially the last three (plyometrics, running/sprinting and games).

During the pre-season, the programme was introduced to the coaches of the intervention teams according to previous research.[15 16] Within the club facilities, the research staff (led by first author, RO) provided instructional courses. They included theoretical and practical training. Coaches received a detailed manual of the programme (online supplemental file 2) and an 'on pitch' card (online supplemental file 3). They were advised to use the programme at least twice a week. During the coaches' instructional courses, there was a focus on the key aspects of the programme, correct postures and movement patterns. Coaches were explicitly instructed to pay attention to those aspects while performing 'FUNBALL'. The correct posture was illustrated and described in detail in the manual of the programme (figure 2). The intervention started 1 week before the clubs' first official match. Research staff visited the intervention teams several times, that is, three to four visits per team in season, to monitor

Figure 2 Example of correct (left) and incorrect (right) posture alignment for one of the exercises provided in the programme (core stability; exercise a).

the quality of programme execution. If coaches needed clarification regarding the exercises, they were advised to contact the research staff, who were continuously available throughout the study period. The coaches of the control group were instructed to perform their training as usual. Prior to the start of the intervention, we gathered more detailed information regarding the training 'routine' of control teams, by interviewing 11 of the 22 coaches. The aim was to collect information whether they performed specific exercises similar to the categories used in the programme. The control group received the programme after the end of the study.

Outcome measures

The primary outcome measure was the overall number of football-related injuries that occurred during the season. Secondary outcomes were region-specific injuries of the lower limbs (hip/groin, thigh, knee, lower leg, ankle and foot) and injury severity (minimal, mild, moderate and severe injuries).

Data collection procedures and definitions

The data collection procedures and definitions used in our study were in line with the consensus statement on injury definitions and data collection procedures.[39] This entailed injury definition, injury severity, mechanism of injury, injury type and location, and definitions for training and match exposure (online supplemental table 1). We collected data during an entire competitive season from August 2021 to May 2022. During the pre-season, the research staff and research assistants collected players' baseline characteristics. The baseline questionnaire included name, age, weight, height, playing position, history of injuries and current health conditions. Throughout the competitive season, the coaches or team's physiotherapists reported to the research assistants team exposure hours, programme execution (compliance) and the new injuries that occurred on a weekly basis. If reporting was delayed for more than 1 week, an automatic message was sent to them. The original plan was to record the injuries and individual exposure hours and report them weekly to the research team via mail. However, most coaches reported that it was too time-consuming. That led to a shift in data reporting practices. The data exchange was subsequently carried out via telephone and we collected team exposure hours instead of individual ones. When new injuries were reported, two research assistants (physiotherapists) blinded to group allocation contacted the injured players (or their parents if players were underage) to obtain the detailed information regarding the injury and its diagnosis, by use of a standardised injury registration form.[18] To increase the accuracy of the data collection, thorough clarification of the protocols for injury classification and injury definitions was carried out for the research assistants before the season started. The exact diagnosis was required in case the player required medical treatment. Most of severe

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injuries (92%) were diagnosed by a physician, partially by one of the coauthors, BS, not connected to any of the clubs assigned for the study and blinded to the group allocation, or other doctors not included in the study. Additionally, the research staff visited all participating teams at the end of the season to add missing or to clarify unclear information by use of individual discussions with involved players. Data on players who dropped out or changed the teams during the season were included until then.

Eight research assistants (two physiotherapists, five students of the last year of physiotherapy school, and one strength and conditioning coach) blinded to group allocation registered the players' basic information and injuries on prepared Excel datasets. We registered all injuries reported from the start of the intervention (1 week ahead of the season, 23 August 2021) until the last match of the season (22 May 2022). If players were already injured at the start of the study, they were included in the study; however, that injury was excluded.

Sample size

A pre-trial sample size calculation based on the data on the incidence of injuries in male adolescent footballers was performed.[2 3] For the primary outcome (overall injuries), we estimated that 78.5% of the players in the control group will sustain an injury during the season.[2] Sample size calculation (comparison of two proportions) revealed that a total of 366 (183 per arm) players are required to achieve 80% power in detecting an estimated 30% reduction in injury rate in the intervention group with an alpha level of 0.05. This is based on the assumption that the team comprises 22 players on average and taking into account an estimated design effect of 2.95. For the second outcome (region-specific injuries), 620 players are required based on the assumption that 64% of players would report a thigh, knee or ankle injury during one season[3] and a similar reduction in injury rate and design effect as above. Based on an expected dropout rate of 30%, we aimed to recruit 806 (403 per arm) football players (approximately 37 teams). We used G*Power software with two-sided Z-test to generate the required sample size.

Statistical methods

All statistical analyses were conducted using Stata statistical software V.17 BE (Stata Corp, Texas, USA). Descriptive statistics were reported for baseline characteristics. Continuous variables (age, height, weight, body mass index and football experience) were reported as mean and SD and were checked for normal distribution. Normal distribution was determined using a histogram, QQ plot and Shapiro-Wilk test. Incidence rate ratios (IRRs) with 95% CIs were calculated according to the intention-to-treat principle for each outcome and compared between the intervention and control groups. We used a Poisson regression model with adjustment for cluster effect. Team was considered as cluster variable. Two-tailed p values were considered significant when the alpha error had a level of less than 0.05. Training exposure was calculated by multiplying the number of training sessions, training time and mean training attendance rate.[14] Match exposure was calculated by multiplying the number of matches, match duration and the number of players on the field.[14] The total football comprised the sum of training and match exposure hours.[24 39] The injury incidence rate (IR) is presented with 95% CI and was calculated according to the formula IR=(n/e)×1000, where (n) is the number of soccer injuries and (e) the total exposure time expressed as total hours of football exposure.[16] Injury burden was calculated as the number of days lost to injury per 1000 hours of football ('injury incidence×mean absence per injury').[40]

Table 2 Player and injury characteristics of the intervention and control groups

Variable	Intervention group	Control group
Player characteristics		
No of teams	23	22
No of players	524	503
Mean (SD) age (years)	15.2 (1.6)	15.3 (1.6)
Mean (SD) height (cm)	171 (9.1)	172 (7.9)
Mean (SD) weight (kg)	60.2 (8.6)	60.5 (8.3)
Mean (SD) BMI (kg/m²)	20.4 (1.5)	20.3 (1.7)
Mean (SD) football experience* (years)	5.0 (1.8)	4.9 (1.6)
Exposure characteristics		
Total exposure (hours)	53 454	52 938
Match exposure (hours)	9 017	8 666
Training exposure (hours)	44 437	44 272
Injury characteristics		
No of total injuries	132	187
No of match injuries	65	91
No of training injuries	67	96
No of injured players	124	172
Injury burden (SD) (days)	40 (3.4)	74 (5.4)

*Football experience taking into account the years since the player has trained at least three times per week.
†Number of injury days lost per 1000 hours.
BMI, body mass index.

Equity, diversity and inclusion statement

The study included a variety of race/ethnicities and socioeconomic levels. The research team consists of two women and four men from different disciplines (physiotherapy, sports psychology, medicine, sports medicine and orthopaedics). It included two junior researchers (RO and RM). As our study was conducted on male football players only, we cannot extrapolate findings to female players. We expand on the exclusion of female players in the discussion.

RESULTS

Participants

The final sample consisted of 45 football teams (1027 players), with 23 teams (524 players) in the intervention group and 22 teams (503 players) in the control group (figure 1). In both clusters, the dropout rate was similar (17.9% in the intervention group and 18.2% in the control group). The players in the two groups who completed the study were similar in terms of baseline characteristics (table 2).

Exposure and injury characteristics

During the season, 106 392 hours of football were recorded. The players in the intervention group were involved in 53 454 hours (44 437 training and 9017 match hours), the players in the control group in 52 938 hours (44 272 training and 8666 match hours) (table 2). 319 injuries occurred: 132 in the intervention and 187 in the control group. The overall injury IR per 1000 football hours for both groups was 2.99 (95% CI 2.68 to 3.34); the training injury IR was 1.83 (95% CI 1.57 to 2.14) and the match injury IR was 8.82 (95% CI 7.54 to 10.32). 296 (28.8%) of the 1027 players suffered an injury. The thigh was the most injured region (n=80; 25.1%; IR 0.75), followed by knee (n=62; 19.4%; IR 0.58) and ankle (n=57; 17.9%; IR 0.53). Players of the age group of the under 19s sustained the highest number of injuries (n=122; 38.2%; IR 4.49) versus the

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Table 3 Effectiveness of the 'FUNBALL' programme in adolescent male football players according to intention to treat

Variable	Intervention group		Control group			
	No of injuries (%)	IR (95% CI)	No of injuries (%)	IR (95% CI)	IRR (95% CI)	P value
Total injuries	132 (100)	2.46 (2.08 to 2.92)	187 (100)	3.53 (3.06 to 4.07)	0.69 (0.55 to 0.87)	0.002
Under 15s injuries	29 (22)	1.43 (0.99 to 2.06)	49 (26.2)	2.77 (2.09 to 3.67)	0.51 (0.32 to 0.82)	0.005
Under 17s injuries	49 (37.1)	2.49 (1.88 to 3.30)	70 (37.4)	3.21 (2.54 to 4.05)	0.77 (0.53 to 1.11)	0.175
Under 19s injuries	54 (40.9)	3.95 (3.03 to 5.16)	68 (36.4)	5.04 (3.97 to 6.39)	0.78 (0.54 to 1.12)	0.184
Location						
Thigh	31 (23.5)	0.57 (0.40 to 0.82)	49 (26.2)	0.92 (0.69 to 1.22)	0.62 (0.39 to 0.98)	0.042
Knee	26 (19.7)	0.48 (0.33 to 0.71)	36 (19.3)	0.68 (0.49 to 0.94)	0.71 (0.43 to 1.18)	0.193
Ankle	23 (17.4)	0.43 (0.28 to 0.64)	34 (18.2)	0.64 (0.45 to 0.84)	0.66 (0.39 to 1.13)	0.138
Hip/groin	15 (11.4)	0.28 (0.16 to 0.46)	21 (11.2)	0.39 (0.25 to 0.60)	0.70 (0.36 to 1.37)	0.306
Lower leg/Achilles tendon	6 (4.6)	0.11 (0.05 to 0.24)	10 (5.4)	0.18 (0.10 to 0.35)	0.59 (0.21 to 1.63)	0.313
Foot/toe	7 (5.3)	0.13 (0.06 to 0.27)	9 (4.8)	0.17 (0.08 to 0.32)	0.77 (0.28 to 2.06)	0.605
Forearm	5 (3.8)	0.09 (0.03 to 0.22)	6 (3.2)	0.11 (0.05 to 0.25)	0.82 (0.25 to 2.70)	0.751
Hand/finger/thumb	5 (3.8)	0.09 (0.03 to 0.22)	6 (3.2)	0.11 (0.05 to 0.25)	0.82 (0.25 to 2.70)	0.751
Head/face/neck	5 (3.8)	0.09 (0.03 to 0.22)	5 (2.7)	0.09 (0.03 to 0.22)	0.99 (0.28 to 3.42)	0.988
Lower back/sacrum/pelvis	4 (3)	0.07 (0.02 to 0.19)	4 (2.1)	0.07 (0.02 to 0.20)	0.99 (0.24 to 3.95)	0.989
Shoulder/clavicle	2 (1.5)	0.03 (0.00 to 0.14)	4 (2.1)	0.07 (0.02 to 0.20)	0.49 (0.90 to 2.70)	0.417
Elbow	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Wrist	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Abdomen	1 (0.8)	0.01 (0.00 to 0.13)	1 (0.5)	0.01 (0.00 to 0.13)	0.99 (0.06 to 15.83)	0.995
Injury mechanism						
Trauma	114 (86.4)	2.13 (1.77 to 2.56)	165 (88.2)	3.11 (2.67 to 3.63)	0.68 (0.53 to 0.86)	0.002
Overuse	18 (13.6)	0.33 (0.21 to 0.53)	22 (11.8)	0.41 (0.27 to 0.63)	0.81 (0.43 to 1.51)	0.508
Injury occurrence						
Training	67 (50.8)	1.50 (1.18 to 1.91)	96 (51.3)	2.16 (1.17 to 2.64)	0.69 (0.50 to 0.94)	0.022
Match	65 (49.2)	7.20 (5.65 to 9.19)	91 (48.7)	10.50 (8.55 to 12.89)	0.68 (0.49 to 0.94)	0.021
Injury severity						
Minimal (1–3 days)	18 (13.6)	0.33 (0.21 to 0.53)	22 (11.8)	0.41 (0.27 to 0.63)	0.81 (0.43 to 1.51)	0.508
Mild (4–7 days)	56 (42.4)	1.04 (0.80 to 1.36)	70 (37.4)	1.32 (1.04 to 1.67)	0.79 (0.55 to 1.12)	0.194
Moderate (8–28 days)	41 (31.1)	0.76 (0.56 to 1.04)	62 (33.2)	1.17 (0.91 to 1.50)	0.65 (0.44 to 0.97)	0.035
Severe (>28 days)	17 (12.9)	0.31 (0.19 to 0.51)	33 (17.6)	0.62 (0.44 to 0.87)	0.51 (0.28 to 0.91)	0.024

IRs are reported per 1000 hours of football play and are unadjusted.
IRRs are adjusted for team.
IR, incidence rate; IRR, incidence rate ratio.

under 17s (n=119; 37.3%; IR 2.87) and the under 15s (n=78; 24.5%; IR 2.06) (table 3). Further injury characteristics data are presented in tables 2 and 3.

Compliance with the 'FUNBALL' programme and training 'routine' of the control teams

The intervention group used the 'FUNBALL' programme in 72.2% of all training sessions, on average 2.2 times per week (online supplemental table 2). The average player attendance for training sessions was 17.2 in the intervention group and 17.5 in the control group. All the interviewed coaches (n=11; 50%) of the control teams reported that they used exercises of similar categories that are contained in the 'FUNBALL' programme. The coaches of the under 15s (n=4; 18.2%) reported they perform balance, core stability and running/sprinting exercises in their training. The coaches of the under 17s and under 19s teams (n=7; 31.8%) reported that they employ core stability, hamstring eccentric, plyometric and running/sprinting exercises, but very rarely balance exercises. The majority of them applied these exercises at least once a week. However, their use was not structured with regard to the number of repetitions, duration and types of exercises.

Efficacy of the intervention programme

For the primary outcome investigated, there was a significantly lower incidence in the intervention group for the overall number of injuries (IRR 0.69, 95% CI 0.55 to 0.87, p=0.002). Secondary outcomes that reached significantly lower incidences in the intervention group were thigh injuries (IRR 0.62, 95%CI 0.39 to 0.98, p=0.042), moderate injuries (IRR 0.65, 95%CI 0.44 to 0.97, p=0.035) and severe injuries (IRR 0.51, 95%CI 0.28 to 0.91, p=0.024). Moreover, a significantly lower incidence was found for match (IRR 0.68, 95%CI 0.49 to 0.94, p=0.021), training (IRR 0.69, 95%CI 0.50 to 0.94, p=0.022) and traumatic injuries (IRR 0.68, 95%CI 0.53 to 0.86, p=0.002). The subgroup analysis according to age groups showed a significantly lower incidence for the overall number of injuries among the under 15 players (IRR 0.51, 95%CI 0.32 to 0.82, p=0.005). The incidence of knee and ankle injuries did not reach significance (table 3). The injury burden was 40 days lost per 1000 hours in the intervention group and 74 days lost per 1000 hours in the control group (table 2). No harmful events associated with the use of the programme, for example, injuries during their execution, were reported by the coaches.

DISCUSSION

Principal findings

The main finding of this study among male young football players is a lower overall injury incidence by one-third in the group that used the 'FUNBALL' programme. Also, training and match injuries were lower in the intervention group when considered separately. Further relevant findings were the programme's efficacy in reducing the incidences of one of the most frequently affected injury regions (thigh), injuries causing the longest time loss in football (moderate and severe injuries) and the injury burden. Thus, players' availability was higher in the teams of the intervention group.

Efficacy of the programme and comparison with previous research

The 'FUNBALL' intervention proved to be successful in a number of aspects. The inclusion of evidence-based exercise categories for prevention of football-related injuries may be one of the main reasons. The first two categories included balance and core stability exercises. Previous studies reported on the efficacy of balance training in reducing ankle ligament injuries in football,[41 42] and the association between impaired core stability and the development of lower extremity injuries in healthy athletes.[43] Hamstring eccentrics were also included in our programme. Their efficacy in preventing hamstring injuries is well-known.[10 11] Even though there is limited evidence regarding the role of gluteal activation for injury prevention, there is evidence that reduced activity represents a risk factor for hamstring injuries.[44] Moreover, the crucial role of gluteal muscles in maintaining a correct knee position, that is, avoiding a dynamic knee valgus, during activities such as walking, running, jumping and landing has been reported.[45] Incorporating plyometric exercises in IPPs has been shown to effectively decrease the risk of anterior cruciate ligament injuries.[46] Finally, and for the first time in connection with IPPs, we introduced sprinting exercises to mitigate hamstring injury risk.[47] Combining many exercise categories makes it (more) difficult to understand which categories provide the highest benefit for reducing injury risk.

A comparison with existing studies is difficult as only very few of them considered our specific age group and male players. The preventive effect on the overall injury incidence is in accordance with two large RCTs investigating the efficacy of 'FIFA11+' in youth female and male football players, respectively.[16 25] Similar to the 'FIFA11+' study conducted in females,[16] 'FUNBALL' reached a significantly positive effect on overall and severe injuries, furthermore on thigh injuries. This may be expected as this type of injury occurs more often in male footballers.[6] Owoeye *et al*[25] investigated youth male football players. They reported an even higher efficacy if the 'FIFA11' programme was employed. The efficacy rate was higher for overall and match injuries compared with our findings. Their figures were 41% and 65%, respectively, as compared with 31% and 32% in our study. In contrast to the 'FUNBALL' study, neither of the two above-mentioned 'FIFA11+' studies reached significant effects with regard to training injuries.[16 25] Additionally, 'FUNBALL' lowered the injury burden and the number of injuries lasting >8 days by about 50%. This can be a highly important point, knowing that a team with lower injury burden and less severe injuries has a better chance of improved team performance.[40] Injury patterns and frequencies differ among different age groups and sexes. Forearm fractures are quite common in children, whereas anterior cruciate ligament ruptures are more common in females aged 16 years and above.[48 49] This (together with lacking statistical power for these particular injury types) may explain why 'FUNBALL' did not show a significant preventive effect in several secondary outcomes, especially in reducing knee injuries.

The efficacy of 'FUNBALL' differed between age groups. The highest efficacy was found among the under 15 players in comparison with under 17 and under 19 players (IRR 0.51 vs 0.77 and 0.78). The reason for this might be the previously mentioned fact by the interviewed coaches that they use similar categories of our programme in their training routine, especially in the older age groups. Therefore, the significant lower injury incidence due to the use of 'FUNBALL' might be mainly attributed to the large effect in the youngest age group. There were no indications that differing compliance with the conduction of the programme was a relevant confounder.

Strengths and limitations

Our study has several strengths. First, the IPP was investigated through a large cluster-randomised trial. We followed good practice by cluster-randomising the clubs to avoid contamination between the control and intervention groups and by blinding the injury data collection assistants. In-season, we regularly visited the clubs without previous announcement to monitor the implementation of the programme. Moreover, we were in contact with players and their parents with regard to detailed injury information in addition to the data provided by coaches or the teams' physiotherapists. Finally, we collected detailed information from the coaches of the control group regarding the exercises that they usually perform during the season with a focus on exercises similar to those used in our intervention programme. This provided a possibility of a more accurate assessment of the efficacy found in our study since an unintentional use of similar exercises would have lowered the effect of the investigated programme.

This study also has some limitations. Despite the inclusion of a football coach, we lacked the input of footballers themselves in the process of developing the intervention. We knew in advance that most of the participating clubs lacked female teams. Thus, it was a conscious decision to confine the study to male teams only. This impacts the strength of clinical recommendations for the programme implementation. We relied on an older version of the data collection methodology[19] as the planning of the study took place before a more sophisticated version[50] was available. The older version lacks some details, especially with regard to 'overuse/growth-related injuries'. Collecting team exposure hours instead of individual exposure hours as it was originally planned is a further limitation, since playing and training time alike can vary greatly among players.[16]

After the start of the study, some barriers appeared in both groups. Four coaches of the intervention teams decided to stop the programme implementation. For them, the small number of coaching staff within the team as well as the limited time for training was the main reason for terminating the programme. In both groups, several coaches presented low motivation for providing the exposure hours and injuries that occurred. Some coaches did not report the data on a weekly basis. We excluded teams from the study if they did not provide the data for a period of 4 weeks. Moreover, the decision of when to progress to the next exercise level was left to the coaches without any guidance from the study assistants. In some cases, we recognised a big difference. Some clubs moved rapidly, within the first weeks of the study, to the most advanced levels, while other clubs still used the initial levels. Finally, the additional time that is required to perform the programme (15–20 min) may be considered as a downside, which however should be weighed against less injured players. The vast majority of the limiting factors listed above potentially impact the programme's success.

Clinical implications, applicability and future research

Reducing football-related injuries holds many benefits both individually for the players as well as for the team. A lower number of injuries, apart from the health benefits, will contribute to the performance of the teams and the financial-related aspects, but it will also increase the likelihood that the young footballers will reach their highest potential. Early adaptation to preventative exercise might, thus, be highly valuable especially at younger ages, as they may serve as a blueprint for an application later in the career. The 'FUNBALL' was investigated among male adolescent football players (aged 13–19 years). Its efficacy in other age groups (seniors and veterans) or female football players was not investigated in our study. This calls for future studies to evaluate the efficacy within these groups. Furthermore, it is recommended investigating the efficacy of the 'FUNBALL' in an even larger cohort and possibly over a longer period of time. This will enable making a comprehensive evaluation of its potential in reducing severe injuries that are less frequent such as anterior cruciate ligament ruptures.

CONCLUSIONS

The 'FUNBALL' programme was effective in lowering the overall injury incidence by 31% in male adolescent football players over an entire season. This also referred to thigh injuries as one of the most frequent football-related injury types, and to moderate and severe injuries, which cause longest absence from football. Therefore, we recommend its implementation in male adolescent football players.

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ORCID iDs
Rilind Obërtinca http://orcid.org/0000-0002-3468-8822
Tim Meyer http://orcid.org/0000-0003-3425-4546

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Research Article

Epidemiology of football-related injuries in young male football players. An additional analysis of data from a cluster-randomised controlled trial

Rilind Obërtinca, Tim Meyer & Karen Aus der Fünten
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ABSTRACT

Football carries a high risk of injury for youth players. The aim of this study was to investigate the epidemiology of football-related injuries in young male players. The data stems from a previously conducted cluster-randomised controlled trial that investigated the efficacy of 'FUNBALL', a new injury prevention programme. This study contains the data of the 503 players of the control arm. The players belonged to 22 football teams of the Under-(U)15, U17 and U19 age groups. The time-loss injuries were recorded during the season 2021–2022 according to the Football Consensus Statement. An analysis on the injury incidence (IR, calculated per 1000 hours of exposure), location, severity, category, and type was performed. Incidence rate ratios (IRRs) were used to compare the variables between the specific age groups. 187 injuries (96 in training and 91 in matches) occurred during 52 938 hours of exposure. The overall IR was 3.53 injuries/1000 h (95% confidence intervals (CI) 3.06 to 4.07). The training IR was 2.16 injuries/1000 h (95% CI 1.17 to 2.64). The match IR was 10.50 injuries/1000 h (95% CI 8.55 to 12.89). In the U19s, the overall IRR was higher compared to the U17s (IRR 1.57, CI 1.12 to 2.19: $p = 0.008$) and compared to the U15s (IRR 1.82, 95% CI 1.25 to 2.62: $p = 0.001$). The thigh was the most commonly affected body region (IR 0.92/1000 h, 95% CI 0.69 to 1.22). Muscle injuries were the most common injury type (IR 1.05/1000 h, 95% CI 0.81 to 1.37). Injury burden was 74 lost days/1000 h. The findings of this study indicate a lower injury incidence in youth players than in adult ones. We observed a higher injury incidence towards the older age groups.

KEYWORDS: Youth football, injury incidence

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