Review

Epidemiology of injuries in male and female youth football players: A systematic review and meta-analysis

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Abstract

Background: To conduct a systematic review and meta-analysis of epidemiological data of injuries in male and female youth football players.
Methods: Searches were performed in MEDLINE/PubMed, Web of Science, Cochrane Library, and SPORTDiscus databases. Studies were considered if they reported injury incidence rate in male and female youth (≤19 years old) football players. Two reviewers (FJRP and ALV) extracted data and assessed trial quality using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement and the Newcastle Ottawa Scale. The Grading of Recommendations Assessment, Development, and Evaluation approach determined the quality of evidence. Studies were combined using a Poisson random effects regression model.
Results: Forty-three studies were included. The overall incidence rate was 5.70 injuries/1000 h in males and 6.77 injuries/1000 h in females. Match injury incidence (14.43 injuries/1000 h in males and 14.97 injuries/1000 h in females) was significantly higher than training injury incidence (2.77 injuries/1000 h in males and 2.62 injuries/1000 h in females). The lower extremity had the highest incidence rate in both sexes. The most common type of injury was muscle/tendon for males and joint/ligament for females. Minimal injuries were the most common in both sexes. The incidence rate of injuries increased with advances in chronological age in males. Elite male players presented higher match injury incidence than sub-elite players. In females, there was a paucity of data for comparison across age groups and levels of play.
Conclusion: The high injury incidence rates and sex differences identified for the most common location and type of injury reinforce the need for implementing different targeted injury-risk mitigation strategies in male and female youth football players.

Keywords: Incidence; Muscle injuries; Severity; Soccer; Young athletes

1. Introduction

Football (soccer) is the most popular sport in the world.[1] Players are required to perform sudden accelerations and decelerations repetitively, rapid changes of directions, and jumping and landing tasks, as well as to be involved in several tackling situations in order to keep possession of or to win the ball.[2,3] These high-intensity situations, alongside frequent exposure to collisions and contacts, result in a notable increase in injury risk compared to individual sports such as tennis[4] and gymnastics.[5] In fact, it has been suggested that football is among the top 5 sports in which players are prone to injury.[6,7] Injuries are also common events among youth footballers, especially at periods of rapid changes in growth and maturation.[8−11] Football-related injuries can counter the health-related beneficial effects of sports participation at a young age if a child or adolescent is unable to continue to participate because of the residual effects of injury.[12]

There is a clear necessity to develop and implement measures (e.g., integrative neuromuscular training,[13] appropriate rule enforcement, and emphasis on safe play[14]) aimed at preventing

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and reducing the number and severity of football-related injuries in youth players. However, before implementing any injury prevention measure, it is essential to know the injury profile of youth football.[15,16] In the past 2 decades, a number of prospective studies have been published describing the incidence and pattern of injuries in youth football players.[17−27] Recently, a systematic review combined and meta-analysed most of the injury incidences available for elite male youth football and reported overall injury rates of 7.9 and 3.7 time-loss injuries per 1000 h of exposure for players aged under (U) 17 to U21 (i.e., players from around age 17 to age 21) and U9 to U16 (i.e., players from around age 9 to age 16), respectively.[28] Furthermore, the same study proposed that a median of 18% (nearly one-fifth) of all reported injuries might be classified as severe (>28 days of absence), with muscle injuries accounting for 37% of all injuries sustained in elite male youth football. However, the systematic review[28] also documented a large disparity in injury incidence rates across primary epidemiological studies and pointed out that pooled incidences of injury patterns (i.e., location, type, mechanism, severity of injuries) have not yet been provided for youth football.

The injury profile in youth male football should not be extrapolated to young female players due to the well-documented anatomical, hormonal, and musculoskeletal sex-related differences.[29,30] In fact, epidemiological studies have pointed out that male youth footballers seem to be more prone to suffer muscle injuries,[9,17,18,20−22,24,25,31−34] whereas ligament sprains are the most frequently diagnosed type of injury in female youth footballers.[27,35] Likewise, disparities in training workloads, medical and performance teams, and physical and mental demands that often exist between elite and sub-elite players and between younger and older age groups might also generate differences in injury incidences according to the level of competition and stages of development.[3,17,33,36] Indeed, some studies have shown that older adolescent football players who are approaching a professional-league level of play are more susceptible to sustaining injuries than their counterparts playing at a grassroots level.[37,38]

The potential for differences by sex in youth football-injury profiles requires meta-analytical investigation to identify accurately the most common and severe types of injuries, as well as where (anatomical location) and when (matches or training sessions) they usually occur in these paediatric cohorts. However, to the best of our knowledge, no systematic review and meta-analysis has been published that describes the injury profile of youth football while analysing potential sex differences in injury patterns. Likewise, disparities in training and match demands require the identification of those levels of play and age groups that may present a higher incidence of injury. Therefore, the main purpose of the current study was to conduct a systematic review and meta-analysis quantifying the incidence of injuries in male and female youth football players. The secondary purpose was to determine the overall effects regarding location of injuries, type of injuries, severity of injuries, mechanism of injuries, type of incident, age groups, and level of play.

2. Methods

This systematic review and meta-analysis was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[39] The PRISMA checklist is presented in Supplementary File 1. The research protocol was registered with PROSPERO (http://www.crd.york.ac.uk/PROSPERO/), registration number CRD42019119279.

2.1. Study selection

Eligibility criteria were established and agreed upon by all authors based on the concept of population, intervention/indicator, comparator/control, outcome, and study design (PICOS)[39,40] (Supplementary File 2).

Thus, to be included in this systematic review and meta-analysis, studies had to fulfil the following criteria:

1) Participants had to be male or female football players ≤19 years old.
2) "Injury" had to be defined in terms of time loss (i.e., an injury that results in a player being unable to take a full part in future football training or match play).[41,42]
3) Eligible studies had to be prospective cohort or randomised control trials (control groups) in order to minimise the occurrence of errors associated with recall.[41,42] The full text of the article reporting results of the study had to be published in English or Spanish in a peer-reviewed journal before January 1, 2021.
4) Eligible studies had to report either injury incidence rate (IIR) or prevalence among the surveyed players separately by sex or provide sufficient data from which these figures could be calculated through standardised equations.

Studies using injury definitions other than time loss were excluded. Literature reviews, abstracts, editorial commentaries, and letters to the editor were also excluded. Finally, 22 authors were contacted for clarification on raw data extraction[9,17,24,32,33,35,43−54] and participant information.[18,19,55,56] Most of the authors contacted (18 out of 22) gave additional details, when requested.[9,18,19,24,32−34,43,44,47−51,53−56]

2.2. Search strategy

A systematic computerised search was conducted for articles published before January 1, 2021, in the databases MEDLINE/PubMed, Web of Science, SPORTDiscus, and Cochrane Library. In addition, a complementary search of the reference lists of included articles and a Google Scholar search were also performed. This was done using backward (manually searching the reference list of a journal article) and forward (scanning a list of articles that had cited a given paper

since it was published) citation tracking.[57] When additional studies that met the inclusion criteria were identified, they were included in the final pool of studies. Relevant search terms were used to construct Boolean search strategies, which can be found in Supplementary File 3.

Two authors (FJRP and ALV) used a 2-step process, independently, to select studies for inclusion in the meta-analysis. First, studies were screened based on title and abstract. Second, the full text of the studies identified after the initial screening were reviewed to identify those studies that met the eligibility criteria. A study was excluded immediately when it failed to meet any of the inclusion criteria. Disagreements were resolved through consensus or by consulting a third author (FA).

2.3. Data extraction

A codebook was produced to standardise the coding of each study in order to maximise the objectivity of coding. Each study was codified by 2 different reviewers (FJRP and ALV). The moderator variables of the eligible studies were coded and grouped into 3 categories: (1) general study descriptors; (2) study population; and (3) epidemiological data (injury (including its main characteristics, e.g., location, type, severity, and mechanism, according to Fuller et al.[41]) and exposure data). If necessary, the authors of the included studies were contacted to provide clarifications or access to raw data. Operational definitions and moderator variables used in our meta-analysis are shown in Supplementary File 4 and Supplementary File 5, respectively.

The purpose of our meta-analysis was to determine the overall effects, separately, on male and female youth football players of (1) football-related IIR (overall *vs.* training *vs.* match); (2) location of injuries (lower extremity *vs.* trunk *vs.* upper extremity *vs.* head and neck); (3) type of injuries (fractures and bone stress *vs.* joint (non-bone) and ligament *vs.* muscle and tendon *vs.* contusions *vs.* laceration and skin lesion *vs.* central/peripheral nervous system *vs.* undefined/other); (4) severity of injuries (slight/minimal (1−3 days) *vs.* minor/mild (4−7 days) *vs.* moderate (8−28 days) *vs.* major/severe (>28 days)); (5) mechanism of injury (overuse *vs.* traumatic injuries; contact *vs.* noncontact); (6) new *vs.* recurrent injuries; (7) age groups (U17−U19, U13−U16, and U12 and below); (8) level of play (sub-elite (low level) *vs.* elite (high level)); and (9) probabilities of injuries over a season.

With regard to the category level of play, players were classified into 1 of 2 labels: sub-elite or elite. Elite players were defined as follows: football players between 8 and 19 years of age whose performance status was described in the studies as "football academy", "high level", or "elite".[28,58] Players not described as belonging to a professional youth academy, playing at a high level, or classified as elite were considered to be sub-elite.

The age group category was classified into 3 different labels in order to reflect the taxonomy of children (U12 and below), pubertal adolescents (U13−U16), and post-pubertal adolescents (U17−U19).

2.4. Quality and risk of bias assessment

The reporting quality of included studies was assessed using an adapted version of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement by von Elm et al.[59] Supplementary File 6 gives a description of the 22 STROBE criteria designed to assess the quality of the studies included in our meta-analysis. The items and subitems of the STROBE statement were scored as 0 or 1, with a score of 1 given for each checklist item that was properly completed. Using this checklist, a maximum score of 34 would indicate that the article fulfilled requirements for a high-quality publication.

Furthermore, to assess risk of bias of external validity quality, an adapted version of the Newcastle Ottawa Scale (NOS) was used.[60] This scale contains 8 items and uses a star rating system to indicate the quality of a study (maximum of 8 stars). The higher the number of stars given to an article, the lower the risk of bias. Supplementary File 7 displays a brief description of each item of the adapted version of the NOS used in our meta-analysis.

The data extraction and quality assessments were conducted by 2 reviewers (FJRP and ALV). To assess the inter-coder reliability of the coding process, these 2 reviewers coded 22 (51%) of the included studies randomly (including quality assessment). For the quantitative moderator variables, intraclass correlation coefficients ($ICC_{3,1}$) were calculated; for the qualitative moderator variables, the Cohen kappa (κ) coefficients were applied. On average, the ICC was 0.84 (range: 0.69−1.00), and the κ coefficient was 0.89 (range: 0.79−1.00), which can be considered highly satisfactory, as proposed by Orwin and Vevea.[61] Inconsistencies between the 2 coders were resolved by consensus, and when they were due to ambiguity in the coding book, they were corrected. As before, any disagreement was resolved by mutual consent in consultation with a third author (FA).

2.5. Quality of the evidence

The quality of the evidence for the overall, training, and match IIRs in male and female youth football players was graded as high, moderate, low, or very low, using a modified the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. Of the 5 GRADE factors, 4 were used in our meta-analysis: risk of bias, inconsistency, imprecision, and indirectness. The fifth factor, publication bias, is difficult to assess in observational studies due to a lack of registries for these types of studies.[62] Therefore, we did not take this factor into account in our meta-analysis. The starting point is always the assumption that the pooled or overall result is of high quality. The quality of evidence was subsequently downgraded by 1 or 2 levels per factor to moderate, low, or very low when there was a risk of bias, inconsistency, imprecision, or indirect results.[63]

2.6. Statistical analysis

IIRs per 1000 h of player exposure were extracted from the included studies. If IIRs were not reported specifically, they

were, if possible, calculated from the available raw data using the following formula:

IIR = 1000 × (∑injuries/∑exposure hours)

Similar to previous meta-analyses of epidemiology of injuries in sports,[60,64,65] data were modelled by a random effects Poisson regression model, as previously described.[66] The response variable in each meta-analysis was the number of observed injuries, offset by the log of the number of exposure hours (IIR). A random effects term was included to account for the correlation arising from using multiple rows of data from the same study. Factors of interest were included as random effects. The following weighting factor was used: study exposure time (h)/mean study exposure time (h). For the IIR, the overall estimated means for each random effect factor were obtained from the model and then back-transformed to give the IIR, along with 95% confidence intervals (95%CIs that showed negative values were adjusted to 0 for better interpretability). Heterogeneity was evaluated using the I^2 statistic, which represents the percentage of total variation across all studies due to between-study heterogeneity.[67] The possible influence of the following variables on the model was analysed independently through univariate and multivariate analyses: registration period, year of publication of the study, age of the players, STROBE score, NOS stars, and number of teams included in the study. Sub-analyses separately by sex were carried out when there were at least 3 IIRs (cohorts) coming from a minimum of 2 different studies and the sum of the number of participants involved was more than 30 players.

Where match IIRs were given per 1000 h, *post hoc* probabilities of injury over a season were determined using the equation developed by Parekh et al.[68] The Poisson distribution for injury probability has been employed previously in football[28] and rugby[69] studies and describes the frequency of injuries occurring, assuming these injuries occur independently and take place over time or space.[70] Probability calculations were based on match durations' being between 40 and 90 min, a conservative 30 matches per season, and injuries being independent events.[28] Injury probability was calculated separately for male and female players and by age group.

All statistical analyses were performed using the statistical software package R version 2.4.1 (The R Foundation for Statistical Computing, Vienna, Austria) and the "metafor" package.[71]

3. Results

3.1. Descriptive characteristics of the studies

A total of 2150 references were identified by all search strategies, of which 43 met the inclusion criteria (resulting in 111 cohort groups, because 19 studies had more than 1 group) (Fig. 1).[9,10,17−27,31−35,43−51,53−56,72−83] These 43 studies were carried out between 1985 and 2020 and comprised male[9,10,17,18,20−25,31−34,43−51,54−56,72−80,82,83] and female[19,26,27,35,43,44,49,51,53,72−74,80,81] players from various (predominantly European) countries. Supplementary File 8 provides a descriptive summary of the characteristics of the included studies.

With regard to the reporting quality of the studies, the mean score obtained with the STROBE quality scale was 23 (minimum = 11; maximum = 32). Regarding the NOS scale, the mean score obtained was 6.5 (minimum = 5; maximum = 8). The quality of evidence according to GRADE was downgraded to moderate (risk of bias and inconsistency) or low (risk of bias, inconsistency, indirectness, and imprecision) for overall, training, and match IIR outcomes in males and females, respectively. The detailed data for STROBE, NOS, and GRADE scales are presented in Supplementary File 9, Supplementary File 10, and Supplementary File 11, respectively.

3.2. Meta-analyses

In the various meta-analyses we carried out, the effect sizes exhibited a moderate to large heterogeneity (based on the Q statistics and the I^2 index), supporting the decision to apply random-effects models.

None of the following had an impact on IIRs: the registration period (i.e., the period of time/year when the data collection process was carried out), the year of publication of the study, age, STROBE score, NOS stars, or number of teams. Hence, the subsequent sub-analyses were not adjusted to these variables.

3.2.1. Injury incidence: Overall, training, and match

Males. Thirty-three studies (38 cohorts) reporting overall IIRs,[9,10,17,18,20−25,31−34,43,45−51,54−56,73,75−79,82,83] 25 studies (30 cohorts) reporting training IIRs,[18,20−22,24,25,31−34,43,45,47−51,54,56,75,77−79,82,83] and 29 studies (34 cohorts) reporting match IIRs[18,20−22,24,25,31−34,43−45,47−51,54,56,72,74,75,77−80,82,83] in male youth football players were included in our meta-analysis, comprising a total of 7495 injuries and about 25,600 different players. The random effect models showed an overall IIR of 5.70 injuries/1000 h (95%CI: 4.54−6.86, $I^2 = 98\%$; quality of evidence = moderate), a training IIR of 2.77 injuries/1000 h (95%CI: 2.04−3.50, $I^2 = 97\%$; quality of evidence = moderate), and a match IIR of 14.43 injuries/1000 h (95%CI: 11.00−17.85, $I^2 = 97\%$; quality of evidence = moderate). Fig. 2 and Fig. 3 display the forest plots with the training and match IIRs, respectively, for males in the analysed studies.

Females. Nine studies (11 cohorts) reporting overall IIRs,[26,27,35,43,49,51,53,73,81] 5 studies (7 cohorts) reporting training IIRs,[27,43,49,51,53] and 10 studies (12 cohorts) reporting match IIRs[19,27,43,44,49,51,53,72,74,80] in female youth football players were included in our meta-analysis, comprising a total of 2179 injuries and about 9600 different players. The random effect models showed an overall IIR of 6.77 injuries/1000 h (95%CI: 5.01−8.52, $I^2 = 94\%$; quality of evidence = low), a training IIR of 2.62 injuries/1000 h (95%CI: 1.16−4.08, $I^2 = 90\%$; quality of evidence = low) and a match IIR of 14.97 injuries/1000 h (95%CI: 9.70−20.24, $I^2 = 96\%$; quality of evidence = low). Fig. 4 and Fig. 5 display the forest plots
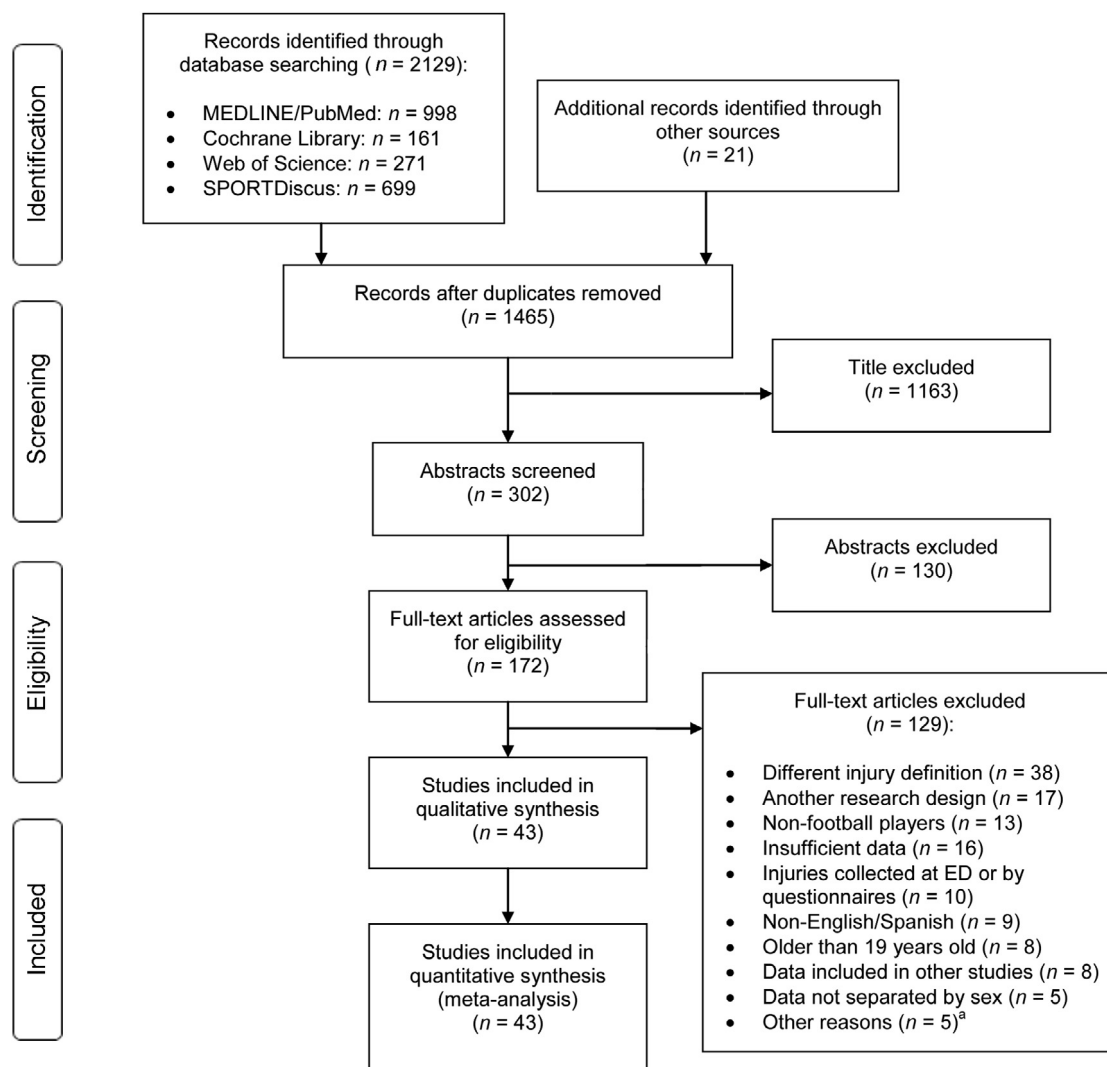
Fig. 1. Flow chart of the selection of studies for the meta-analysis. [a] No injury definition (*n* = 2), full-text not available (*n* = 2), and incidence for football players reported jointly with other sports (*n* = 1). ED = emergency departments.

with the training and match IIRs, respectively, for females in the analysed studies.

3.2.2. Location of injury

Males. Twenty-four studies reported injury location and lower-extremities-region categories (based on Fuller et al.[41]) in males.[9,17,18,20,21,23−25,31−34,43,45,47,48,50,54,56,77−79,82,83] Lower-extremity injuries had the highest IIR (IIR = 4.08 injuries/1000 h; 95%CI: 2.92−5.24, $I^2 = 99.5$%) compared to injuries in other body regions. The upper limbs region was the second most commonly injured region (IIR = 0.29 injuries/1000 h; 95%CI: 0.20−0.39, $I^2 = 94.7$%); the trunk region was third (IIR = 0.25 injuries/1000 h; 95%CI: 0.17−0.34, $I^2 = 92.9$%), and injuries to the head and neck region had the lowest IIR (IIR = 0.08 injuries/1000 h; 95%CI: 0.04−0.12, $I^2 = 88.5$%). Regarding lower-extremity injuries, the thigh showed the highest IIR (IIR = 1.21, 95%CI: 0.74−1.69, $I^2 = 99.1$%), followed by ankle ((IIR = 0.91, 95%CI: 0.64−1.18, $I^2 = 97.6$%), knee (IIR = 0.75, 95%CI:

0.53−0.97, $I^2 = 96.6$%), hip/groin (IIR = 0.73, 95%CI: 0.45−1.00, $I^2 = 98.1$%), lower leg/Achilles tendon (IIR = 0.37, 95%CI: 0.24−0.50, $I^2 = 94.4$%), and foot/toe (IIR = 0.31, 95%CI: 0.19−0.43, $I^2 = 94.9$%) (Fig. 6).

Females. Only 5 studies reported injury location and lower-extremities region categories in female youth footballers.[26,27,35,43,53] The trend was similar to that for males, with lower extremities having the highest IIR (IIR = 6.54 injuries/1000 h; 95%CI: 4.68−8.40, $I^2 = 91.4$%), followed by trunk (IIR = 0.68 injuries/1000 h; 95%CI: 0.54−0.82, $I^2 = 0$%) and upper limbs (IIR = 0.26 injuries/1000 h; 95%CI: 0.12−0.39, $I^2 = 51.0$%), with the lowest IIR related to head and neck injuries (IIR = 0.13 injuries/1000 h; 95%CI: 0.00−0.34, $I^2 = 68.2$%). With regard to lower-extremity injuries, ankle (IIR = 1.52, 95%CI: 1.19−1.86, $I^2 = 64.0$%) and knee (IIR = 1.49, 95%CI: 0.90−2.08, $I^2 = 89.3$%) showed the highest IIRs, followed by thigh (IIR = 1.06, 95%CI: 0.55−1.56, $I^2 = 91.0$%), lower leg/Achilles tendon (IIR = 0.68, 95%CI: 0.28−1.08, $I^2 = 90.2$%), hip/groin (IIR = 0.57, 95%CI:

Study	IIR (95%CI)
Azuma et al. (2020)[47]	2.29 (1.65 – 2.93)
Bianco et al. (2016)[24]	1.15 (0.91 – 1.39)
Brito et al. (2011)[34]	1.80 (1.22 – 2.38)
Brito et al. (2012)[33]	0.90 (0.75 – 1.05)
Cezarino et al. (2020)[22]	1.43 (1.16 – 1.69)
Chena-Sinovas et al. (2019)[21]	2.66 (2.28 – 3.05)
Ergün et al. (2013)[31]	7.40 (3.53 – 11.27)
Frisch et al. (2011)[32]	7.10 (5.62 – 8.58)
Hägglund et al. (2009a)[51]	0.00
Hägglund et al. (2009b)[51]	1.50 (0.00 – 4.47)
Hägglund et al. (2009c)[51]	2.09 (0.00 – 4.99)
Hägglund et al. (2009d)[51]	1.20 (0.00 – 3.55)
Hägglund et al. (2009e)[51]	1.46 (0.00 – 4.32)
Hägglund et al. (2009f)[51]	5.60 (0.71 – 10.49)
Hawkins et al. (1999)[56]	4.10 (3.04 – 5.16)
Imai et al. (2018)[54]	4.57 (2.88 – 6.26)
Junge et al. (2004)[75]	3.67 (2.10 – 5.24)
Kakavelakis et al. (2003)[77]	3.30 (2.68 – 3.92)
Kuzuhara et al. (2017)[43]	1.42 (0.62 – 2.22)
Nielsen et al. (1989)[78]	3.60 (1.63 – 5.57)
Nilsson et al. (2016)[20]	5.60 (3.93 – 7.27)
Nogueira et al. (2017)[25]	2.06 (1.67 – 2.45)
Owoeye et al. (2014)[79]	0.40 (0.24 – 0.56)
Raya-González et al. (2019)[18]	1.98 (1.72 – 2.24)
Rommers et al. (2020)[48]	2.03 (1.77 – 2.29)
Sieland et al. (2020)[45]	2.30 (1.83 – 2.77)
Sprouse et al. (2020)[49]	3.62 (3.00 – 4.23)
Waldén et al. (2007)[82]	2.90 (0.00 – 6.42)
Wik et al. (2020)[50]	8.19 (7.55 – 8.82)
Zarei et al. (2020)[83]	1.21 (0.81 – 1.61)
Total	2.77 (2.04 – 3.50)

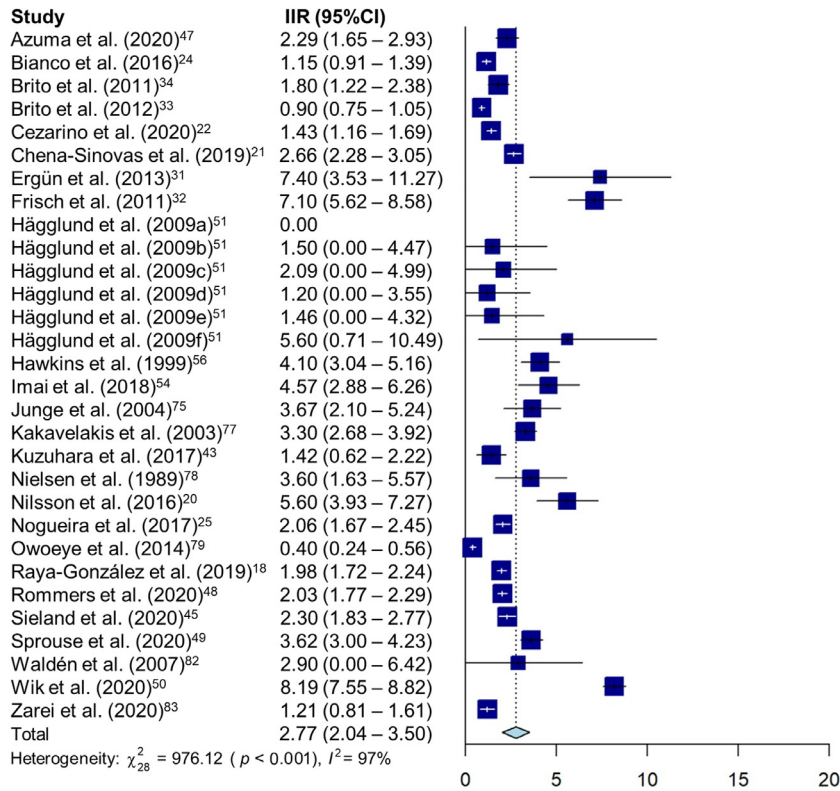Heterogeneity: $\chi^2_{28} = 976.12$ ($p < 0.001$), $I^2 = 97\%$

Fig. 2. Training injury incidence in male youth football players, with 95%CI. a, b, c, d, e, and f indicate different cohorts in the same study. 95%CI = 95% confidence interval.

Study	IIR (95%CI)
Andreasen et al. (1992)[72]	3.60 (2.86 – 4.34)
Azuma et al. (2020)[47]	11.90 (8.43 – 15.38)
Bianco et al. (2016)[24]	2.84 (1.65 – 4.03)
Brito et al. (2011)[34]	6.80 (3.58 – 10.02)
Brito et al. (2012)[33]	4.70 (3.48 – 5.92)
Cezarino et al. (2020)[22]	6.41 (4.16 – 8.67)
Chena-Sinovas et al. (2019)[21]	8.88 (6.97 – 10.79)
Ergün et al. (2013)[31]	30.40 (15.01 – 45.79)
Frisch et al. (2011)[32]	23.50 (18.15 – 28.85)
Hägglund et al. (2009a)[51]	16.30 (5.00 – 27.60)
Hägglund et al. (2009b)[51]	27.80 (13.24 – 42.36)
Hägglund et al. (2009c)[51]	21.83 (8.93 – 34.72)
Hägglund et al. (2009d)[51]	20.70 (7.86 – 33.54)
Hägglund et al. (2009e)[51]	12.58 (2.51 – 22.64)
Hägglund et al. (2009f)[51]	28.60 (13.06 – 44.14)
Hawkins et al. (1999)[56]	37.20 (30.22 – 44.18)
Imai et al. (2018)[54]	6.24 (2.55 – 9.93)
Junge et al. (2013)[74]	28.39 (24.93 – 31.84)
Junge et al. (2004)[75]	16.20 (12.06 – 20.34)
Kakavelakis et al. (2003)[77]	5.60 (4.50 – 6.70)
Kuzuhara et al. (2017)[43]	5.44 (2.48 – 8.39)
Nielsen et al. (1989)[78]	14.40 (6.92 – 21.88)
Nilsson et al. (2016)[20]	15.50 (8.34 – 22.66)
Nogueira et al. (2017)[25]	14.22 (11.74 – 16.70)
Owoeye et al. (2014)[79]	20.30 (15.64 – 24.96)
Raya-González et al. (2019)[18]	8.84 (7.22 – 10.45)
Rommers et al. (2020)[48]	9.72 (8.21 – 11.22)
Schmidt-Olsen et al. (1985)[80]	7.40 (5.99 – 8.81)
Sieland et al. (2020)[45]	5.00 (3.27 – 6.73)
Soligard et al. (2012)[44]	3.87 (3.29 – 4.45)
Sprouse et al. (2020)[49]	26.53 (22.71 – 30.34)
Waldén et al. (2007)[82]	30.40 (15.04 – 45.76)
Wik et al. (2020)[50]	31.98 (29.10 – 34.87)
Zarei et al. (2020)[83]	10.01 (6.00 – 14.02)
Total	14.43 (11.00 – 17.85)

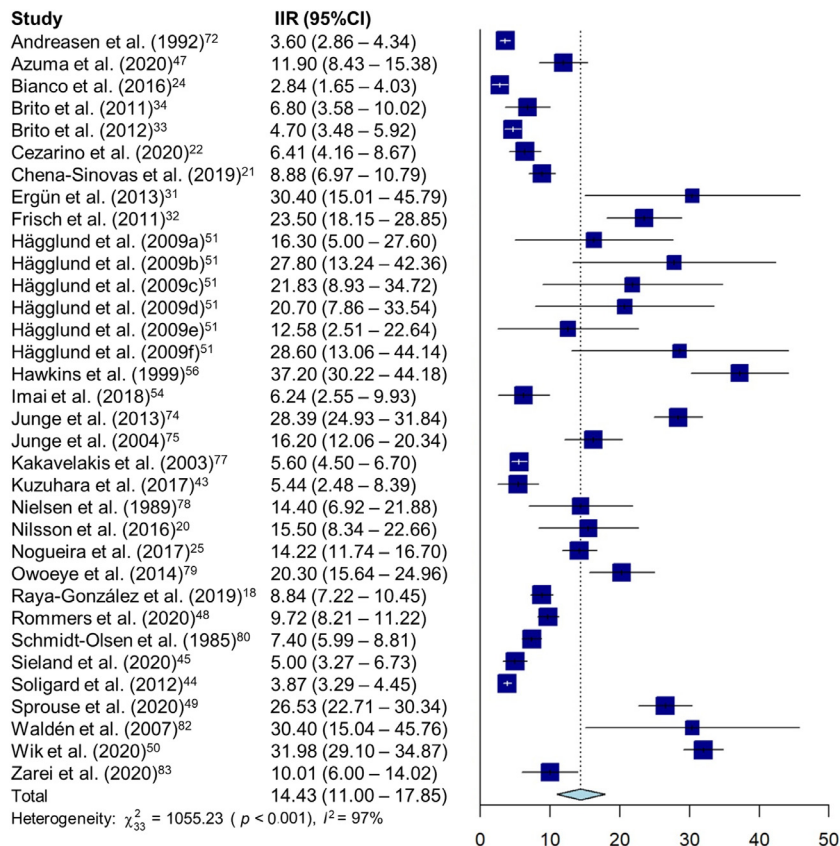Heterogeneity: $\chi^2_{33} = 1055.23$ ($p < 0.001$), $I^2 = 97\%$

Fig. 3. Match injury incidence in male youth football players, with 95%CI. a, b, c, d, e, and f indicate different cohorts in the same study. 95%CI = 95% confidence interval.
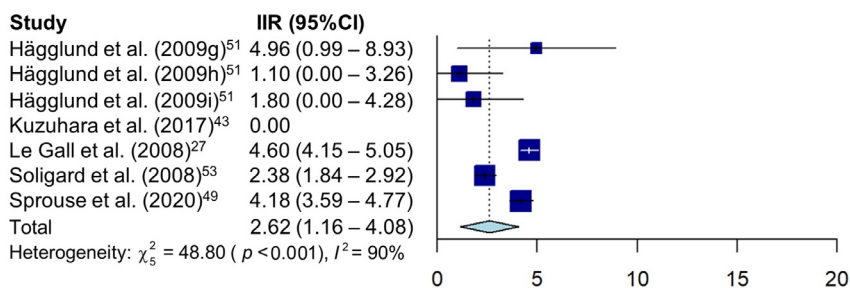
Fig. 4. Training injury incidence in female youth football players, with 95%CI. g, h, and i indicate different cohorts in the same study. 95%CI = 95% confidence interval.
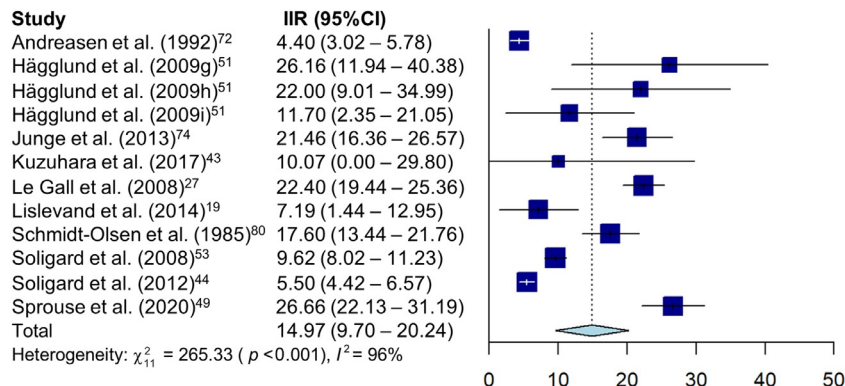

Fig. 5. Match injury incidence in female youth football players, with 95%CI. g, h, and i indicate different cohorts in the same study. 95%CI = 95% confidence interval.

$0.19-0.96$, $I^2 = 91.9\%$), and foot/toe (IIR = 0.40, 95%CI: $0.31-0.49$, $I^2 = 0\%$) (Fig. 6).

3.2.3. Type of injury

Males. Fifteen studies reported the type of injury among male players.[9,17,18,21,24,25,31−34,43,47,48,50,82] The most common type of injury grouping was muscle/tendon (IIR = 1.92 injuries/1000 h; 95%CI: $1.26-2.58$, $I^2 = 99.0\%$), followed by joint (non-bone)

Fig. 6. Location of injuries in male (left side) and female (right side) youth football players. The upper boxes (with solid lines extending from them) represent the incidence of injury for main groups (head and neck, upper limbs, trunk, lower limbs), whereas the lower boxes (with dashed lines extending from them) represent the incidence of injury for lower extremities categories (hip/groin, thigh, knee, lower leg/Achilles tendon, ankle, foot/toe).

and ligament (IIR = 0.97 injuries/1000 h; 95%CI: $0.64-1.30$, $I^2 = 97.4\%$) and contusions (IIR = 0.84 injuries/1000 h; 95%CI: $0.37-1.30$, $I^2 = 99.3\%$). Fracture and bone stress (IIR = 0.43 injuries/1000 h, 95%CI: $0.02-0.84$, $I^2 = 99.7\%$), undefined/other (IIR = 0.27 injuries/1000 h; 95%CI: $0.04-0.50$, $I^2 = 99.5\%$), central/peripheral nervous system (IIR = 0.06 injuries/1000 h; 95%CI: $0.00-0.12$, $I^2 = 95.6\%$) and laceration and skin lesions (IIR = 0.03 injuries/1000 h; 95%CI: $0.01-0.05$, $I^2 = 66.0\%$) were the least common types of injury.

Females. Only 3 studies reported type of injury in females players and were the only 3 pooled in our meta-analysis.[27,35,43] Unlike injuries in males, joint (non-bone) and ligament injuries (IIR = 2.36 injuries/1000 h; 95%CI: $1.62-3.11$, $I^2 = 59.0\%$) were the most common type of injury among females, followed by muscle and tendon injuries (IIR = 2.01 injuries/1000 h; 95%CI: $1.75-2.28$, $I^2 = 0\%$), contusions (IIR = 0.93 injuries/1000 h; 95%CI: $0.61-1.25$, $I^2 = 44.6\%$), undefined/other (IIR = 0.84 injuries/1000 h; 95%CI: $0.49-1.20$, $I^2 = 57.0\%$), and fracture and bone stress injuries (IIR = 0.27 injuries/1000 h; 95%CI: $0.17-0.36$, $I^2 = 0\%$). No laceration or skin lesions or central/peripheral nervous system injuries were registered.

3.2.4. Severity of injury

Males. Twenty-one studies (26 cohorts) reported severity of injury in males.[9,17,18,20,21,23,25,31−34,45−48,50,51,56,79,82,83] Minimal injuries (IIR = 1.88 injuries/1000 h; 95%CI: $1.13-2.64$,

$I^2 = 99.8\%$) were the most common, followed by moderate (IIR = 1.74 injuries/1000 h; 95%CI = 1.30−2.18, $I^2 = 98.0\%$), mild (IIR = 1.13 injuries/1000 h; 95%CI: 0.77−1.49, $I^2 = 98.5\%$), and severe (IIR = 0.78 injuries/1000 h; 95%CI: 0.56−1.00, $I^2 = 96.4\%$). Additionally, a total of 11 studies[9,18,23−25,31−34,46,83] reported an average of 15.5 days lost per injury by male footballers, with an overall injury burden of 96.47 injury days/1000 h of football exposure (95%CI: 49.86−143.08, $I^2 = 100\%$).

Females. Only 3 studies (5 cohorts) reported on the severity of injuries in females.[19,51,53] Minimal injuries (IIR = 3.60 injuries/1000 h; 95%CI: 0.68−6.53, $I^2 = 82.3\%$) were also the most usual in females, followed by moderate (IIR = 1.52 injuries/1000 h; 95%CI: 1.18−1.87, $I^2 = 0\%$), severe (IIR = 1.25 injuries/1000 h; 95%CI: 0.57−1.94, $I^2 = 43.1\%$), and mild (IIR = 0.76 injuries/1000 h; 95%CI: 0.51−1.00, $I^2 = 0\%$). The paucity of data prevented the calculation of pooled estimates for the injury burden among female footballers.

3.2.5. Mechanism of injury

Males. In our meta-analysis, 16 studies (19 cohorts) provided data for the comparison of overuse injuries to traumatic (acute) injuries among males.[9,18,20,21,23,25,31−33,49−51,54,56,79,82] The IIR for traumatic injuries (IIR = 5.50 injuries/1000 h, 95%CI: 3.98−7.01) was higher than for overuse injuries (IIR = 1.10 injuries/1000 h, 95%CI: 0.68−1.53). In relation to the mechanism of injury, 15 studies (18 cohorts) reported data that allowed us to compare contact injuries to noncontact injuries among males.[9,21,25,31−33,45,47,49−51,55,56,79,82] Males showed a slightly higher IIR for noncontact injuries (IIR = 3.48 injuries/1000 h, 95%CI: 2.35−4.62) than for contact injuries (IIR = 2.77 injuries/1000 h, 95%CI: 1.93−3.61).

Females. Eight studies (9 cohorts) provided data for the comparison of overuse injuries to traumatic (acute) injuries among females.[19,26,27,35,49,51,53,81] Similar to the IIR for males, the IIR for traumatic injuries (IIR = 4.55 injuries/1000 h, 95%CI: 3.72−5.38) among females was higher than for overuse injuries (IIR = 1.56 injuries/1000 h, 95%CI: 0.80−2.31). Four studies (5 cohorts) reported data that allowed us to compare contact injuries to noncontact injuries among females.[49,51,53,81] Similar IIRs for noncontact injuries (IIR = 2.39 injuries/1000 h, 95%CI: 1.80−2.98) and for contact injuries (IIR = 1.92 injuries/1000 h, 95%CI: 1.67−2.17) were found.

3.2.6. New vs. recurrent injuries

Males. Included in our analysis were 11 studies (14 cohorts) that aimed to compare the IIR for new injuries to the IIR for recurrent injuries among males.[9,24,25,31−34,48,50,51,56] The IIR for new injuries (IIR = 5.87 injuries/1000 h, 95%CI: 3.89−7.84) was higher than that for recurrent injuries (IIR = 0.81 injuries/1000 h, 95%CI: 0.38−1.25).

Females. Five studies (6 cohorts) provided data that allowed us to compare the IIR for new injuries to the IIR for recurrent injuries among females.[26,27,35,51,81] Similar to the IIR for males, the IIR for new injuries (IIR = 5.12 injuries/1000 h, 95%CI: 3.64−6.61) was higher than the IIR for recurrent injuries (IIR = 1.42 injuries/1000 h, 95%CI: 0.29−2.55) among female footballers.

3.2.7. Age groups

Males. Concerning the age of football players, we categorised footballers into 3 groups: U12 and below, U13−U16, and U17−U19. For males, 20 studies (58 cohorts)[9,18,21−25,31,33,43,46,49−51,54−56,77,78,82] provided data that allowed us to compare the overall IIR; 16 studies (46 cohorts)[9,18,21,22,24,25,31,43,49−51,54,56,77,78,82] provided data that allowed us to compare training IIRs; and 19 studies (55 cohorts)[9,18,21,22,24,25,31,43,44,49−51,54,56,74,77,78,80,82] provided data that allowed us to compare match IIRs. The U17−U19 male age group showed the highest overall IIR (IIR = 7.54 injuries/1000 h; 95%CI: 5.62−9.47, $I^2 = 97\%$), followed by the U13−U16 male group (5.35 injuries/1000 h, 95%CI: 3.73−6.98, $I^2 = 98\%$), and the U12 male group (IIR = 1.61 injuries/1000 h; 95%CI: 0.76−2.45, $I^2 = 85\%$). In particular, the mean IIRs in training decreased from the U17−U19 age group (IIR = 3.51 injuries/1000 h; 95%CI: 2.15−4.87, $I^2 = 91\%$) to the U13−U16 age group (IIR = 3.39 injuries/1000 h, 95%CI: 2.20−4.57, $I^2 = 95\%$) to the U12 age group (IIR = 1.07 injuries/1000 h; 95%CI: 0.40−1.74, $I^2 = 72\%$). The match IIRs for each age group were, in descending order: U17−U19 (IIR = 20.05 injuries/1000 h; 95%CI: 15.48−24.62, $I^2 = 93\%$), U13−U16 (IIR = 13.67 injuries/1000 h; 95%CI: 8.49−18.86, $I^2 = 95\%$), and U12 (IIR = 2.60 injuries/1000 h; 95%CI: 0.60−4.59, $I^2 = 77\%$).

Females. Only 2 studies (5 cohorts) provided data that allowed us to compare overall and training IIRs for females,[49,51] and only 6 studies (15 cohorts) provided data that allowed us to compare match IIRs.[19,44,49,51,74,80] The U17−U19 female age group had an overall IIR of 6.25 injuries/1000 h (95%CI: 4.68−7.81, $I^2 = 38\%$), a training IIR of 3.08 injuries/1000 h (95%CI: 2.18−3.98, $I^2 = 40\%$), and a match IIR of 20.94 injuries/1000 h (95%CI: 14.27−27.62, $I^2 = 78\%$). The U13−U16 female age group reported a match IIR of 12.67 injuries/1000 h (95%CI: 5.41−19.94, $I^2 = 89\%$). The scarcity of studies reporting overall, training and match IIRs for the U12 and below female age group, and overall and training IIRs for the U13−U16 female age group, prevented further sub-analyses for these groups.

3.2.8. Level of play

Males. Regarding the level of play, studies were classified into 2 groups: sub-elite and elite. Ten studies reported overall IIRs,[21,25,32−34,43,47,54,75,76] 9 studies reported training IIRs,[21,25,32−34,43,47,54,75] and 9 studies reported match

IIRs[21,25,32−34,43,47,54,75] in sub-elite players. The random effect models showed an overall IIR of 4.77 injuries/1000 h (95%CI: 2.63−6.90, $I^2 = 98\%$), a training IIR of 2.83 injuries/1000 h (95%CI: 1.39−4.27, $I^2 = 96\%$), and a match IIR of 10.63 injuries/1000 h (95%CI = 5.98−15.28, $I^2 = 93\%$).

For its part, the elite level was represented by 20 (25 cohorts) overall IIR studies,[9,10,17,18,20,22−24,31,45,46,48−51,55,56,79,82,83] 14 (19 cohorts) training IIR studies,[18,20,22,24,31,45,48−51,56,79,82,83] and 16 studies (21 cohorts) from competitions.[18,20,22,24,31,44,45,48−51,56,74,79,82,83] The random effect models showed an overall IIR of 6.19 injuries/1000 h (95%CI: 4.56−7.82, $I^2 = 99\%$), a training IIR of 2.68 injuries/1000 h (95%CI: 1.64−3.72, $I^2 = 98.0\%$), and a match IIR of 17.91 injuries/1000 h (95%CI: 12.99−22.83, $I^2 = 98\%$).

Females. Three studies (4 cohorts) reported overall IIR[26,35,43] in sub-elite female players, with the random effect models displaying a total of 7.86 injuries/1000 h of football exposure (95%CI: 3.27−12.44, $I^2 = 78\%$). An insufficient number of studies were found to estimate training and match IIRs in sub-elite female players.

On the other hand, 4 studies (6 cohorts) reported overall,[26,27,49,51] 3 studies (4 cohorts) reported training,[27,49,51] and 5 studies (6 cohorts) presented match[27,44,49,51,74] IIRs in elite female players. The overall IIR was 6.49 injuries/1000 h (95%CI: 5.76−7.23, $I^2 = 50\%$), 3.24 injuries/1000 h of training (95%CI: 1.60−4.89, $I^2 = 79\%$), and 18.13 injuries/1000 h of match (95%CI: 9.43−26.82, $I^2 = 98\%$).

3.2.9. Probability of Injury

The overall injury probability during 1 season was 47% and 43% for male and female youth players, respectively. Independent of sex, the highest injury probability was found for the U17−U19 age groups (56% in males and 58% in females) and was lowest for the U12 age group (7% in males and 18% in females). The U13−U16 age group had an injury probability of 39% for males and 30% for females. Supplementary File 12 provides a descriptive summary of the probabilities of injury for both male and female cohorts.

4. Discussion

Both the methodology and the statistical analyses used in our study were identical to those used in the systematic reviews and meta-analyses conducted by López-Valenciano et al.[60,84] for adult men (elite football players) and women (sub-elite and elite football players). Although injury profile comparisons between youth and adult football players are possible, our comparisons should be interpreted with a certain degree of caution due to inter-meta-analyses differences in the number of cohorts and quality of the studies included in each analysis.

4.1. Injury incidence: Overall, training, and match

The main findings in our study indicate that the overall, training, and match IIRs in male youth football players (5.7 injuries/1000 h, 2.8 injuries/1000 h, and 14.4 injuries/1000 h

of overall, training and match exposure, respectively) and female youth football players (6.8 injuries/1000 h, 2.6 injuries/1000 h, and 15.0 injuries/1000 h of overall, training and match exposure, respectively) are higher than the IIRs found in previous studies related to other youth team sports such as handball (2.9 injuries/1000 h, 0.9 injuries/1000 h, and 9.9 injuries/1000 h of overall, training and match exposure, respectively);[85] basketball (1.3 injuries/1000 h, 0.5 injuries/1000 h, 11.2 injuries/1000 h of overall, training and match exposure, respectively);[86] and volleyball (2.4 injuries/1000 h of match exposure).[87] Furthermore, the probability of youth football players' sustaining a time-loss injury during a season was 47% for male players and 43% for female players. These probability-of-injury scores are higher than the 28% score reported for child and adolescent rugby players during a rugby season.[69] The high IIRs and probability scores found for youth footballers in our meta-analysis reinforce the need for implementing targeted injury risk mitigation strategies in youth football.

For adult football players[60,84] and players in other youth team sports (independent of the players' sex), such as handball,[85] basketball,[86] volleyball,[87] and rugby,[69] match IIRs have always been found to be significantly higher than training IIRs. A number of studies have attributed the difference in IIRs between match and training to several factors, including the higher physical playing demands during matches compared to the demands of training sessions, the greater variability and uncertainty in game demands when competing against rivals (compared to the familiarity of training with teammates), the number of contacts and collisions during matches, and the fatigue generated during the course of a match.[38,88,89]

4.2. Location and type of injuries

Similar to the rates that have been reported for adult footballers, lower-extremity injuries had the highest IIRs compared to the other body regions among both male and female youth football players (4.1 injuries/1000 h and 6.5 injuries/1000 h, respectively).

The locations of the most frequently reported injuries in male and female youth footballers were slightly different. In male players, the thigh (1.2 injuries/1000 h) and ankle (0.9 injuries/1000 h) were the anatomical regions where injuries occurred most frequently, whereas the knee (1.5 injuries/1000 h) and ankle (1.5 injuries/1000 h) were the regions where injuries were reported most frequently among females. The higher knee and ankle IIRs found for female youth football players in our meta-analysis may be explained by the fact that females sustained twice as many joint (non-bone) and ligament injuries as their male counterparts (2.4 injuries/1000 h for females and 1.0 injuries/1000 h for males). This higher susceptibility for sustaining joint and ligament injuries observed in female youth football players in comparison with their male counterparts has also been found in adult football players. Sex-related differences in core and lower extremity neuromuscular control, joint laxity, hormonal regulation, biomechanics, and anatomy[29,30,90] have been suggested (among other factors) as reasons why female athletes are more prone to suffering joint

(non-bone) and ligament injuries, mainly around the knee and ankle joints. Because of the lack of epidemiological studies reporting IIRs separately for joints (non-bone) and ligaments (e.g., anterior cruciate ligament of the knee and anterior inferior tibiofibular ligament of the ankle) among youth footballers, a subanalysis aimed at identifying the most commonly injured joint (non-bone) and ligament was not possible. However, previous studies have consistently reported that ankle sprains were the most frequent joint and ligament injuries diagnosed in youth football players, independent of the sex of the players.[8,18,27,35]

In our meta-analysis, the thigh was the area most frequently injured in male football players. However, no sex-related differences were found in the magnitude of thigh IIRs ($\sim$1.1 injuries/1000 h for both male and female players). This circumstance strongly correlates with the fact that both male and female youth football players also presented analogous muscle IIRs ($\sim$2 injuries/1000 h). The link between these 2 IIRs can be found in the fact that hamstring and quadriceps muscle injuries, both operationally located in the thigh,[41] have been consistently reported as the most frequently diagnosed injuries in youth football players (and also in adult players).[8,38,91] However, the very limited number of studies available that reported IIRs separately by muscle group prevented us from calculating pooled estimates for hamstring and quadriceps muscle injuries. In contrast, it should be noted that, among adult football players, men and women did not report similar muscle injury rates. In particular, male footballers presented muscle IIRs that were twice as high as women's IIRs (4.6 injuries/1000 h *vs.* 1.8 injuries/1000 h, respectively), which might be attributed to the larger intersex differences in physical match demands (e.g., number of high-intensity actions performed) that are evident in elite football.[92]

Interestingly, the IIRs related to trunk injuries were more than twice as high for female footballers as for male footballers (0.7 injuries/1000 h *vs.* 0.3 injuries/1000 h, respectively) but were still relatively low for both sexes. A more erect posture during landing has been evidenced in females, which could overload not only the lower limbs but also the trunk area.[90] Consequently, this may increase the risk of trunk injuries (e.g., spondylolisthesis) for females. Therefore, it would be advisable for prevention programs for females to focus on core strength also.

Current international research has also given particular attention to head injuries that involve the nervous system (i.e., concussions and traumatic brain injuries). Our results in this area showed the lowest IIRs for head and neck injuries (0.1 injuries/1000 h) and for injuries to the central/peripheral nervous system (<0.1 injuries/1000 h) in both males and females, which matches the findings of previous large-scale investigations.[93,94] However, these injuries might be underdiagnosed frequently due to inconsistencies in the interpretation and reporting of the symptoms.[95] Thus, the use of a definition of a time-loss injury may have reduced the proportion of concussion injuries pooled in our research. Future prospective studies using a more accurate injury definition, as well as a recognition of and reporting on this type of injury, are needed to analyse the evidence on the incidence of concussions among youth footballers.

4.3. Severity and mechanisms of injuries

Although injuries occur frequently in youth football players, the majority of injuries, fortunately, appear to be of minimal severity (1−3 days lost). However, it should be highlighted that the IIRs for moderate injuries (1.7 injuries/1000 h for males and 1.5 injuries/1000 h for females) and for severe injuries (0.8 injuries/1000 h for males and 1.3 injuries/1000 h for females) found in our meta-analysis may be considered problematic. In practical terms, our findings might imply that in a typical youth football squad comprising 20 players, a coach could expect 2 high-burdensome injuries (>28 days of time loss) per season (value calculated using the data provided in original studies[9,18,20,21,23,25,31−34,45,47,48,50,51,53,56,79,82,83]). Results of our study have revealed that a great proportion of injuries in male and female youth footballers might have traumatic and noncontact mechanisms and, as such, they can be regarded as preventable. The implementation of comprehensive injury prevention programs aimed at improving movement competency and physical fitness among youth footballers has demonstrated that this can be a successful approach to reducing the number of moderate and severe noncontact injuries in children and adolescents.[53,96] Previous studies have demonstrated that 10−15 min of neuromuscular training activities 2 to 3 times weekly reduces noncontact injuries by 45% in youth football players.[97]

Although injuries to adult football players can have negative effects on a team and its success rate,[98] the impact of injuries on the development of youth football players has yet to be established. However, it may be assumed that at young ages, being away from football play for more than 28 days may not only negatively influence the short-term tactical, technical, and physical performance of youth football players but may also impair their long-term development, health outcomes, and future career opportunities.[12,99] Because the studies included in our meta-analysis reported only IIRs, not the average number of days lost from football (time loss) by location and type of injury, it was not possible for us to calculate the injury burden and, thus, build a risk matrix. A risk matrix would have helped to identify the importance (i.e., burden) of each football-related injury and provided information that could have helped prioritise injury-prevention measures used in applied football environments. However, based on the findings from previous studies,[46,100] the most burdensome injuries in youth football may well be quadriceps and hamstring muscle injuries, knee ligament injuries (anterior cruciate ligament tears) and growth-related injuries (Osgood-Schlatter and Sinding-Larsen diseases). In terms of the severity and mechanisms of injuries described for youth football players, this injury pattern is very similar to that reported by López-Valenciano et al.[60,84] for adult footballers.

4.4. New vs. recurrent injuries

As expected, and similar to the findings reported elsewhere concerning adult football players,[60,84] the IIRs for recurrent injuries in youth footballers is lower than the IIRs for new injuries (0.8 injuries/1000 h for males and 1.4 injuries/1000 h for females *vs.* 5.9 injuries/1000 h for males and 5.1 injuries/1000 h for females, respectively). Likewise, there were no sex-related

differences in new and recurrent injuries in either youth or adult football players. However, it should be highlighted that the ratio of new injuries to recurrent injuries was higher among youth players (7.4 for male youths *vs*. 5.4 for male adults[60] and 3.6 for female youths *vs*. 2.6 for female adults[84]).

The lower recurrent IIRs in youth players in comparison with their adult counterparts may indicate that at young ages there is not such high pressure to return to play as soon as possible, contributing to improved rehabilitation.[58,101] On the other hand, having a previous history of injury is one of the few evidence-based predictors available in the literature for the most common football-related injuries (i.e., hamstring and knee injuries).[102−104] As a consequence of having more experience in playing football, adult footballers may present a higher likelihood of having suffered previous injuries than youth players; hence, adults may be at a higher risk of injury recurrence.[105,106] This circumstance has led some researchers to suggest that the main purpose of injury-risk-mitigation strategies in youth football should be to delay, as much as is possible, the occurrence of the first injury.[105,107] Longitudinal studies that track IIRs through the academy setting and into professional environments might help to elucidate whether there is a consequence of repeated injuries during growth and maturation.[108]

4.5. Age groups

Results from the various age groups, representing differing periods of childhood and adolescence, suggest potential interactions among maturity, sex, training, and competition with IIRs. In males, the overall IIR increased among players who are likely to be prepubertal (U12), circapubertal (U13−U16), or postpubertal (U17−U19),[109] with overall IIRs of 1.6 injuries/1000 h, 5.3 injuries/1000 h, and 7.5 injuries/1000 h of football exposure, respectively. This was driven by a high IIR for matches, which increased by approximately 10 injuries between each consecutive age interval (2.6 injuries/1000 h *vs*. 13.7 injuries/1000 h *vs*. 20.0 injuries/1000 h). The changing profile of the IIR is likely to be attributable to both maturation effects and increasing demands of training and competition in older age groups. Young children have an immature neuro-muscular and metabolic system, with a lower muscle mass, more compliant muscle-tendon structures, and less ability to recruit fast-twitch fibres, with an underdeveloped anaerobic system and a greater reliance on aerobic metabolism.[110] All these factors mean that immature players work less explosively and that they generate and have to tolerate lower levels of force, thus exposing themselves to lower levels of risk. At the same time, they experience lower levels of fatigue during intermittent work and are able to recover from fatigue more quickly.[111] This is reflected in the fact that U12 players have low overall and low match IIRs. Adolescent players experience a period of rapid physical development that will result in gains in both size and fitness, but this developmental period can be accompanied with temporarily disrupted motor coordination.[112] Consequently, adolescent players may begin to expose themselves to a greater intensity and volume of

exercise within training and match play and may display aberrant movement mechanics while also being more susceptible to growth and overuse injuries.[8,10,113] They may also have a reduced ability to recover between matches.[114] All these factors may contribute to a higher IIR for adolescent players compared to prepubertal players.

Players continue to develop physically into late adolescence and early adulthood and will likely continue to increase their abilities to work at high intensities, completing more accelerations, decelerations, and greater total distances during competition compared to younger players.[115] The increased physical demands and longer duration of match play mean that players in the older age groups are exposing themselves to more risk during a game. Simultaneously, players transitioning to older age groups (U17−U19) are likely to experience a great increase in training load as they begin to train on full-time professional contracts,[8] and these spikes in workload have been suggested to contribute to injuries among youth football players.[8,116] These increases in IIRs across players' age groups are also evident when compared with the results reported by López-Valenciano et al.[60] for adult footballers, where IIRs reach up to 8.1 injuries/1000 h, 3.7 injuries/1000 h, and 36.0 injuries/1000 h for overall, training and match exposure, respectively.

There was a paucity of data available to compare IIRs across age groups for female players. Only 2 studies reported overall and training IIRs for females in the U17−U19 age groups,[49,51] and although a few others have presented match injury data for females in the U13−U16 and U17−U19 cohorts, most of these studies correspond to football tournaments,[19,44,51,74,80] and 1 was published in 1985.[80] Based on the available information, females who were in the U17−U19 group experienced a higher incidence of match-related injuries than U13−U16 females (20.9 injuries/1000 h *vs*. 12.7 injuries/1000 h, respectively), which is similar to the increase described for males. However, more research with longer follow-up periods is needed to confirm the potential differences between age groups in females, especially across a range of maturational stages.

4.6. Level of play

The findings from our study also indicate that elite (high-level) male players present a higher match IIR (17.9 injuries/1000 h) than their sub-elite (less skilled) peers (10.6 injuries/1000 h). These observed differences according to the level of play may be partially explained by the fact that elite players perform more high-intensity actions during competitions and, as has been mentioned, this would potentially increase their risk of sustaining injuries. In addition, players skilled in receiving the ball, passing, shooting, and decision making with the ball at their feet have more ball possession and, consequently, are exposed to more tackles and other contact situations.[117] Furthermore, highly skilled young players are often required to compete on teams of older players. This scenario not only forces younger players to compete against more mature and physically bigger players but also to potentially play 2 matches within a very short time interval (usually less

than 36 h), which may overload their immature musculoskeletal system and significantly increase their risk of injury.[118] In this regard, Dupont et al.[119] found that decreased recovery time between matches leads to an increase in IIRs. Finally, the professionalisation of youth football has meant that many youngsters in professional academies become single-sport specialists.[28] High weekly training volumes associated with early specialisation may promote limited participation in other sports, decreasing motor skill development and increasing injury risk as players transition to new development cycles.[120,121] Elite young football players who strive to be professional players may also be exposed to high levels of pressure.

However, in our study, no differences in training IIRs were found regarding the level of play for males. It is reasonable to suggest that elite players have access to better resources than do their sub-elite peers, including better equipment, comprehensive medical support, and expert coaches who can control match and training loads. These superior resources may contribute to a reduction in injury risk despite their expected greater exposure to training.[17]

Although elite female youth footballers showed IIRs that were similar to those shown for males, there was a lack of data related to training and matches for sub-elite female players. Future studies should analyse the injury profile for this cohort of female football players, reporting the number of injuries sustained in matches and training sessions separately.

4.7. Level and quality of the evidence

In our systematic review and meta-analysis, the pooled results of more than 25 epidemiological studies provided a moderate quality of evidence for support of the overall, training and match IIRs estimated for male youth football players. The quality of evidence for overall, training and match IIRs in females was low, coming from only 5 (training)[27,43,49,51,53] to 10 (match)[19,27,43,44,49,51,53,72,74,80] studies. Furthermore, several of these studies were carried out with female players who were selected to participate in various tournaments,[19,44,51,72,74,80] a situation that represents a shorter period of time for data collection compared to an entire football season. Therefore, future research should focus on monitoring IIRs among female youth football players throughout competitive seasons in order to provide a broader comparison with the IIRs documented among male youth footballers.

4.8. Limitations

Although our study was conducted following the international guidelines for systematic reviews and meta-analyses, some limitations should be acknowledged. Variations in injury definitions and data collection procedures used in the various studies might partly explain the heterogeneous estimates obtained in our meta-analysis and in previous meta-analyses conducted in the field of sport medicine.[28,60,69,84] To mitigate this problem, we included in our sub-analysis only those studies that rigorously and clearly followed the time-loss injury definition described by Fuller et al.[41] and Hägglund et al.[42] The inclusion of injuries requiring medical attention may well

have led to higher IIRs. However, it could also intensify the differences between data-collection procedures because non-time-loss IIRs have been shown to be especially sensitive to differing recording settings, and a research−invested clinical recorder might report almost a 9 times greater IIR compared to other noninvolved recorders (i.e., noninvolved physiotherapists).[122] Thus, and based on the reality of injury surveillance among youth football players, where coaches are frequently the responsible person for recording injuries[35,43,44,73,78] due to the lack of medical staff, a time-loss definition was used. Furthermore, because different epidemiological data were presented in the included studies (e.g., total number of injuries, number of matches played), we applied standardised formulas to account for this discrepancy. Nevertheless, even when these inclusion criteria and standardised formulas were applied, the degree of inconsistency of the main results (overall, training and match IIRs) across studies was still very high. Consequently, other aspects of football—such as differences in geographic areas or time of year affecting climatic conditions for football practice,[123] the monitoring period of the season,[33,34] the number of exposure hours and match congestion,[17] or the skill level of youth footballers[117]—may have constituted other sources of inconsistency. The limited number of studies reporting the location and type of injuries for elite and sub-elite players by sex made further sub-analyses in this area impossible. Such sub-analyses may have identified potential differences attributable to the level of play. However, given the results of previous studies on elite[9,17,18,31,50,82] and sub-elite[21,25,32−34] male and elite[27] and sub-elite[35] female players, large differences in these injury patterns might not be expected. Finally, the sample sizes of the included studies were not sufficient to investigate the interactive effects of physical maturation, growth spurt, or growth-related injuries on IIRs among young football players.

5. Conclusion

The high IIRs and probability scores found for youth footballers in our meta-analysis reinforce the need for implementing targeted injury risk-mitigation strategies in youth football, irrespective of sex. Because IIRs are higher during match play for both sexes, it is important that the training prescription mimic the demands of match play as closely as possible in order to provide the robustness and readiness needed for competitive play. The sex differences identified for the most common locations and types of injury reinforce the need for different targeted management strategies in male and female youth players. Males tend to sustain predominantly muscle injuries to the thigh, and females sustain predominantly joint and ligament injuries to the knee and ankle, so strategies should focus on neuromuscular conditioning in male players and movement mechanics, core strength, and joint stability in female players. However, there is still a paucity of data concerning female players, especially for younger and less mature female players. Additional longitudinal studies are needed to fully explore the age- and maturation-related changes in incidence, severity, location, and type of injuries that occur among footballers of both sexes.

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Authors' contributions

FJRP, ALV, and FA designed the research, conducted the searches and screening process, extracted the data, interpreted the data analysis, and led the drafting of the manuscript; AGG performed all the statistical analyses; MDSC, JLO, and PSdB assisted in the interpretation of the data analysis and contributed to the drafting of the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2021.10.002.

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