Robles-Palazón, Francisco, López-Valenciano, Alejandro, De Ste Croix, Mark B ORCID logoORCID: https://orcid.org/0000-0001-9911-4355, Oliver, Jon L., García-Gómez, A, Sainz de Baranda, Pilar and Ayala, Francisco (2022) Epidemiology of injuries in male and female youth football players: a systematic review and meta-analysis. Journal of Sport and Health Science, 11 (6). pp. 681-695. doi:10.1016/j.jshs.2021.10.002

Official URL: https://doi.org/10.1016/j.jshs.2021.10.002
DOI: http://dx.doi.org/10.1016/j.jshs.2021.10.002
EPrint URI: https://eprints.glos.ac.uk/id/eprint/10010

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

Running head: Epidemiology of injuries in youth football

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

Abstract

Purpose: 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 PubMed, Web of Science, Cochrane Library and SPORTDiscus databases. Studies were considered if they reported injury incidence rate among male and female youth (≤19 years) football players. Two reviewers extracted data and assessed trial quality using the STROBE statement and 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 5.7 and 6.8 injuries/1000h in males and females, respectively. Match injury incidence (14.4 [males] and 15.0 [females] injuries/1000h) was significantly higher than training (2.8 [males] and 2.6 [females] injuries/1000h). The lower extremity had the highest incidence rates in both sexes. The most common types of injuries were 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. In females, there was a paucity of data to compare 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: soccer, incidence, severity, young athletes, muscle injuries.

1. Introduction

Football (soccer) is the most popular sport in the world.[1] Players are required to repetitively perform sudden accelerations and decelerations, rapid changes of directions, jumping and landing tasks, as well as being involved in several tackling situations 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] or gymnastics.[5] In fact, it has been suggested that football is among the top 5 injury-prone sports.[6,7] Injuries are also common events in 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 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 last two 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 has combined and meta-analysed most of the incidences available in elite male youth football and has reported overall injury rates of 7.9 and 3.7 time-loss injuries per 1000 hours of exposure for players aged under (U) 17 to U21 and U9 to U16 years old, respectively.[28] Furthermore, this study has 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, this systematic review[28] has also documented a large disparity in injury incidence rates across primary epidemiological studies and pointed out that pooled incidences for injury patterns (i.e., location, type, mechanism, and severity of injuries) have not yet been provided in 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 players.[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 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 the professional-league level of play are more susceptible to sustaining injuries than their counterparts playing at a grass-roots level.[37,38]

The potential for differences in injury profile in youth football by sex requires meta-analytical investigation to accurately identify the most common and severe 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 the authors´ knowledge, no systematic review and meta-analysis has been published describing 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 Material 1. The research protocol was registered with the PROSPERO International prospective register of systematic reviews (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] (for more information, please see Supplementary Material 2).

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

Participants had to be male or female football players younger than or equal to 19 years old.
Injury must be defined in terms of time loss (i.e., injury that results in a player being unable to take a full part in future football training or match play).[41,42]

The study had to be prospective cohort or randomised control trials (control groups), to minimise the occurrence of errors associated with recall,[41,42] and the full-text article had to be published in English or Spanish in a peer-reviewed journal before January 2021.

Eligible studies must 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 further details, where requested.[9,18,19,24,32–34,43,44,47–51,53–56]

2.2. Search strategy

A systematic computerised search was conducted up to 31st December 2020 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 (to manually search 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 Material 3.

Two reviewers independently (FJR-P and AL-V) selected studies for inclusion in a two-step process. First, studies were screened based on title and abstract. Second, full-text studies were reviewed to identify those studies that met the eligibility criteria. A study was excluded immediately once it failed to meet a single inclusion criterion. Disagreements were resolved through consensus or by consulting a third reviewer (FA).

2.3. Data extraction

A codebook was produced to standardise the coding of each study in order to maximise the objectivity and each study was codified by 2 different reviewers. 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 applicable, the authors of included studies were contacted to provide clarifications or access to raw data. Operational definitions and moderator variables used in this study are shown in Supplementary Material 4 and 5, respectively. The purpose of the current meta-analysis was to determine the overall effects of: 1) football-related IIR (overall vs. training vs. match) in male and female youth players, 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. non-contact), 6) new vs. recurrent injuries, 7) age groups (U17-U19: 16-19 years old; U13-U16: 12-16 years old; U12: lower than 12 years old), 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, studies were classified into 2 different labels: sub-elite and elite. Elite players were defined as follows: youth or adolescent elite youth football players between 8 and 19 years of age whose performance status was described 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 as 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 Vom Elm et al.[59] Supplementary Material 6 displays a description of the 22 criteria designed to assess quality of the studies included in the meta-analysis with the STROBE scale. The items and subitems of the STROBE statement were scored as 0 or 1, with a score of 1 provided for each checklist item that was properly completed. Using this checklist, a maximum score of 34 would indicate 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 Material 7 displays a brief description of each item of the adapted version of the NOS used in this study.

The data extraction and quality assessments were conducted by 2 reviewers (FJR-P and AL-V). To assess the inter-coder reliability of the coding process, these 2 reviewers (FJR-P and AL-V) coded 22 studies randomly (54%) (including quality assessment). For the quantitative moderator variables intra-class correlation coefficients ($ICC_{3,1}$) were calculated, while for the qualitative moderator variables Cohen’s kappa coefficients were applied. On average, the ICC was 0.84 (range: 0.69-1.0) and the kappa coefficient was 0.89 (range: 0.79-1.0), which can be considered highly satisfactory, as proposed by Orwin et al.[61] Inconsistencies between the 2 coders were resolved by consensus, and when these were due to ambiguity in the coding book, this was corrected. As before, any disagreement was resolved by mutual consent in consultation with a third reviewer (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 (high, moderate, low, or very low evidence) using a modified GRADE approach. Four of the five GRADE factors were used in this 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 this 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 hours of player exposures were extracted from the included studies. If IIRs were not specifically reported, they were, if possible, calculated from the available raw data using the following formula:

$$\text{IIR} = 1000 \text{ x } (\sum\text{injuries}/\sum\text{exposure hours})$$

Similar to previous meta-analysis on 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 (IIRs). 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. A weighting factor used was: study exposure time (hours) / mean study exposure time (hours). For IIR, the overall estimated means for each random effect factor were obtained from the model and then back-transformed to give IIR, along with 95% CIs (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 the study publication, 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 higher than 30 players.

Where match IIR was given per 1000h, post hoc probabilities of injury over a season were determined using the following equation developed by Parekh et al.[68] The Poisson distribution for injury probability has previously been employed in football[28] and rugby[69] studies, and can describe the frequency of injuries occurring that is assuming these injuries occur independently and take place over time or space.[70] Probability calculations were based on match duration 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 also by age groups.

All statistical analyses were performed using the statistical software package R Version 2.4.1 (The R Foundation for Statistical Computing) and the “metafor” package.[71]

3. Results

3.1. Descriptive characteristics of the studies

A total of 2150 references were identified with all search strategies, of which 43 met the inclusion criteria (resulting in 111 cohort groups as 19 studies had more than one group) (Figure 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 different countries, especially in Europe. Table 1 provides a descriptive summary of the characteristics of the included studies.

With regards to the reporting quality of the studies, the mean score obtained with the STROBE quality scale was 23 (minimum: 11, maximum: 32). Regarding 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) and 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 Material 8, 9 and 10, respectively.

3.2. Meta Analyses

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

Neither registration period (i.e., the period of time/year when the data collection process was carried out), nor the year of publication of the study, age, STROBE score, NOS stars, and number of teams’

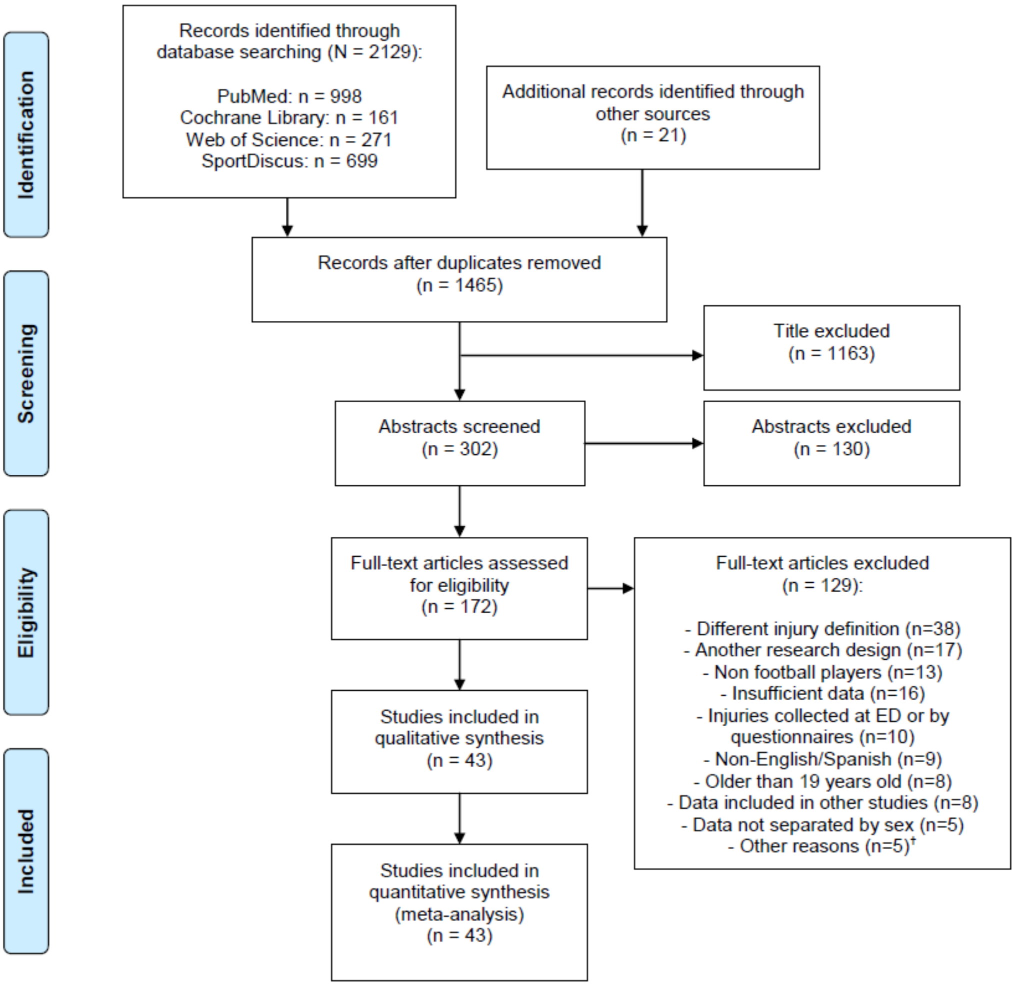

Figure 1 Flow chart of the selection of studies for the meta-analysis. †No injury definition (n=2), full-text not available (n=2), and incidence for football players reported jointly with other sports (n=1).

variables had an impact on IIRs and 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 IIR,[9,10,17,18,20–25,31–34,43,45–51,54–56,73,75–79,82,83] 25 studies (30 cohorts) reporting training IIR[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 IIR[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 this meta-analysis, comprising a total of n = 7495 injuries and around 25600 different players. The random effect models showed an overall IIR of 5.7 injuries/1000h (95%CI = 4.5-6.9, I^2 = 98.0%, quality of evidence = moderate), a training IIR of 2.8 injuries/1000h (95%CI = 2.0-3.5, I^2 = 97.0%, quality of evidence = moderate) and a match IIR of 14.4 injuries/1000h (95%CI = 11.0-17.8, I^2 = 97.0%, quality of evidence = moderate). Figures 2-3 display the forest plots with the training and match IIR of the analysed studies.

Table 1. Characteristics of the studies included in the meta-analysis.

Reference	Study	Participants			Exposure (hours)			Injuries			Incidence			STROBE - /34	NOS - /8
Continent (or event) / Year / Level of play	duration (weeks)	Sex (cohort)	Age (range)	Teams (players)	Overall	Training	Match	Overall	Training	Match	Overall	Training	Match	(reporting quality)	(methodological quality)
Andreasen et al.[72] IT / 1991 / EL	1	M	U19 (10-19)	- (9586)	-	-	25527	-	-	92	-	-	3.6	16	5
		F	U19 (10-19)	- (3321)	-	-	8890	-	-	39	-	-	4.4		
Azuma et al.[47] F Control AS / 2018-19 / SEL	40	M	U18 (15-18)	- (60)	25188	21408	3780	94	49	45	3.7	2.3	11.9	28	7
Backous et al.[73] NA / - / MI	3	M	U17 (6-17)	- (681)	14931.5	-	-	109	-	-	7.3	-	-	15	5
		F	U17 (6-17)	- (458)	10094.3	-	-	107	-	-	10.6	-	-		
Bianco et al.[24] F EU / 2012-13 / EL	44	M (a)	U16 (13-16)	- (54)	59058	53616	5442	72	60	12	1.2	1.2	2.2	20	6
		M (b)	U19 (17-19)	- (23)	24302	21984	2318	35	25	10	1.4	1.1	4.3		
		M (T)	U19 (13-19)	- (80)	83360	75600	7760	107	85	22	1.3	1.2	2.8		
Brito et al.[34] F EU / 2009 / SEL	6	M	U19 (12-19)	40 (741)	23364	20847	2517	53	37	16	2.5	1.8	6.8	21	5
Brito et al.[33] F EU / 2008-09 / SEL	43	M (a)	U12 (11-12)	- (179)	41666.7	-	-	25	-	-	0.6	-	-	22	7
		M (b)	U14 (13-14)	- (169)	37272.7	-	-	41	-	-	1.1	-	-		
		M (c)	U16 (15-16)	- (165)	40714.3	-	-	57	-	-	1.4	-	-		
		M (d)	U18 (17-18)	- (161)	44705.9	-	-	76	-	-	1.7	-	-		
		M (T)	U18 (11-18)	28 (674)	161850	149803	12047	199	139	60	1.2	0.9	4.7		
Bult et al.[23] F EU / 2013-16 / EL	117	M (a)	U12 (U12)	- (17)	3583	-	-	21	-	-	5.9	-	-	26	7
		M (b)	U13 (U13)	- (50)	9965	-	-	51	-	-	5.1	-	-		
		M (c)	U14 (U14)	- (54)	11332	-	-	84	-	-	7.4	-	-		
		M (d)	U15 (U15)	- (54)	11175	-	-	139	-	-	12.4	-	-		
		M (e)	U16 (U16)	- (53)	13066	-	-	113	-	-	8.7	-	-		
		M (f)	U17 (U17)	- (38)	11761	-	-	119	-	-	10.1	-	-		
		M (g)	U19 (U19)	- (43)	13475	-	-	93	-	-	6.9	-	-		
		M (T)	U19 (U12-19)	- (170)	74358	-	-	620	-	-	8.3	-	-		

Cezarino et al.[22] [F] SA / 2017 / EL	52	M (a)	U11 (10-11)	- (23)	4883.8	4516.7	367.1	2	1	1	0.4	0.2	2.7	29	8
		M (b)	U12 (11-12)	- (22)	4456.1	3908	548	8	8	0	1.8	2	0		
		M (c)	U13 (12-13)	- (25)	8120.4	7572.2	548.1	6	3	3	0.7	0.4	5.5		
		M (d)	U14 (13-14)	- (28)	12834.8	12394.8	440	21	17	4	1.6	1.4	9.1		
		M (e)	U15 (14-15)	- (28)	13176.4	12420.5	755.8	12	10	2	0.9	0.8	2.6		
		M (f)	U16 (15-16)	- (25)	12386.4	11731.2	655.2	27	24	3	2.2	2	4.6		
		M (g)	U17 (16-17)	- (28)	15084.9	14060.2	1024.7	46	32	14	3	2.3	13.7		
		M (h)	U18 (17-18)	- (16)	10359	9864	495	18	14	4	1.7	1.4	8.1		
		M (T)	U18 (10-18)	- (195)	81301.7	76467.8	4833.9	140	109	31	1.7	1.4	6.4		
Chena-Sinovas et al.[21] [F] EU / - / SEL	40	M (a)	U9 (7-9)	- (68)	8337.4	7492.8	844.7	19	12	7	2.3	1.6	8.3	15	6
		M (b)	U11 (10-11)	- (80)	14830.3	13290.3	1540	23	17	6	1.6	1.3	3.9		
		M (c)	U13 (12-13)	- (114)	22518	19681.9	2836.2	55	52	3	2.4	2.6	1.1		
		M (d)	U15 (14-15)	- (71)	14973.8	12905.8	2068	69	41	28	4.6	3.2	13.5		
		M (e)	U18 (16-18)	- (69)	18121.4	16058.9	2062.5	102	63	39	5.6	3.9	18.9		
		M (T)	U18 (7-18)	- (402)	78781	69429.6	9351.3	268	185	83	3.4	2.7	8.9		
Clausen et al.[26] [F] EU / 2012 / MI(T), EL(a), SEL(b)(c)	20	F (a)	U18 (15-18)	- (-)	6434	-	-	59	-	-	9.2	-	-	27	6
	20	F (b)	U18 (15-18)	- (-)	6811	-	-	63	-	-	9.2	-	-		
	20	F (c)	U18 (15-18)	- (-)	13761	-	-	140	-	-	10.2	-	-		
	20	F (T)	U18 (15-18)	32 (438)	27746	-	-	269	-	-	9.7	-	-		
Delecroix et al.[55] [F] EU / 2013-17 / EL	156	M	U19 (16-19)	- (52)	23947.4	-	-	182	-	-	7.6	-	-	25	7
Ërgun et al.[31] [F] EU / 2005-08 / EL	117	M	U19 (U17-19)	- (52)	2390.2	1897	493.2	29	14	15	12.1	7.4	30.4	21	6
Fouasson-Chailloux et al.[46] [F] EU / 2011-16 / EL	195	M	U15 (13-15)	- (-)	44436	-	-	417	-	-	9.4	-	-	23	6
Frisch et al.[32] [F] EU / 2007-08 / SEL	44	M	U19 (13-19)	- (67)	15673.1	12519.3	3153.7	163	89	74	10.4	7.1	23.5	27	7
Hägglund et al.[51] (a) [F] EC / 2006 / EL	2	M	U19 (U19)	8 (144)	1253	762	490	8	0	8	6.4	0	16.3	25	6
Hägglund et al.[51] (b) [F] EC / 2007 / EL	2	M	U19 (U19)	8 (147)	1158	654	504	15	1	14	13	1.5	27.8	25	6

Hägglund et al.[51] (c) [F] EC / 2008 / EL	2	M	U19 (U19)	8 (145)	1461	957	504	13	2	11	8.9	2.1	21.8	25	6
Hägglund et al.[51] (d) [F] EC / 2006 / EL	2	M	U17 (U17)	8 (144)	1316	834	482	11	1	10	8.4	1.2	20.7	25	6
Hägglund et al.[51] (e) [F] EC / 2007 / EL	2	M	U17 (U17)	8 (145)	1161	685	477	7	1	6	6	1.5	12.6	25	6
Hägglund et al.[51] (f) [F] EC / 2008 / EL	2	M	U17 (U17)	8 (144)	1354	899	455	18	5	13	13.3	5.6	28.6	25	6
Hägglund et al.[51] (g) [F] EC / 2006 / EL	2	F	U19 (U19)	8 (144)	1707	1210	497	19	6	13	11.1	5	26.2	25	6
Hägglund et al.[51] (h) [F] EC / 2007 / EL	2	F	U19 (U19)	8 (144)	1407	906	501	12	1	11	8.5	1.1	22	25	6
Hägglund et al.[51] (i) [F] EC / 2008 / EL	2	F	U19 (U19)	8 (145)	1635	1121	514	8	2	6	4.9	1.8	11.7	25	6
Hawkins et al.[56] EU / 1994-97 / EL	117	M	U18 (16-18)	- (30)	16832.5	13902.4	2930.1	166	57	109	9.9	4.1	37.2	17	5
Imai et al.[54] [F] Control AS / 2014-15 / SEL	32	M	U14 (12-14)	- (38)	7888	6126	1762	39	28	11	4.9	4.6	6.2	20	7
Junge et al.[74] (a) [F] WC / 1999-2011 / EL	19	M	U17 (U17)	136 (2856)	-	-	9124.5	-	-	259	-	-	28.4	23	6
Junge et al.[74] (b) [F] WC / 2008-12 / EL	9	F	U17 (U17)	48 (1008)	-	-	3168	-	-	68	-	-	21.5	23	6
Junge et al.[75] OC / 2001 / SEL	24	M	U18 (14-18)	12 (145)	9352.5	5727.5	3639.5	80	21	59	8.6	3.7	16.2	21	6
Junge et al.[76] Control EU / 1999-00 / SEL	52	M	U19 (14-19)	7 (93)	13094.4	-	-	100	-	-	7.6	-	-	22	7
Kakavelakis et al.[77] EU / 1999-00 / -	40	M	U15 (12-15)	24 (287)	52250	33333.3	17678.6	209	110	99	4	3.3	5.6	17	6
Kuzuhara et al.[43] AS / 2013-14 / SEL	52	M	U12 (≤12)	5 (86)	10838.4	8447.7	2390.8	25	12	13	2.3	1.4	5.4	22	7
		F	U12 (≤12)	- (3)	377.7	278.4	99.3	1	0	1	2.6	0	10.1		
Le Gall et al.[27] [F] EU / 1998-06 / EL	312	F	U19 (15-19)	- (119)	97325	87530	9795	619	400	219	6.4	4.6	22.4	24	7

Lislevand et al.[19] F AF / 2008 / SEL	0.3	F (a)	U13 (≤13)	37 (433)	-	-	431	-	-	5	-	-	11.6	27	5
		F (b)	U16 (13-16)	14 (213)	-	-	403	-	-	1	-	-	11.7		
		F (T)	U16 (≤16)	51 (646)	-	-	834	-	-	6	-	-	7.2		
Nielsen et al.[78] EU / 1986 / MI	44	M	U18 (16-18)	2 (30)	4554	3564	990	27	13	14	5.9	3.6	14.4	15	8
Nilsson et al.[20] F EU / 2013-14 / EL	88	M	U19 (15-19)	- (43)	10367	7678.6	1161.3	61	43	18	6.8	5.6	15.5	22	8
Nogueira et al.[25] F EU / 2015-16 / SEL	26	M (a)	U16 (15-16)	11 (290)	33673	28598.5	5074.5	138	73	65	3.7	2.1	12.6	29	7
		M (b)	U19 (17-19)	10 (239)	28389	24561	3828	110	46	64	4	2	16		
		M (T)	U19 (15-19)	21 (529)	62062	53159.5	8902.5	248	119	129	3.9	2.1	14.2		
Owoeye et al.[79] F Control AF / 2012-13 / EL	24	M	U19 (14-19)	10 (204)	61045	57448	3597	94	22	73	1.5	0.4	20.3	27	7
Raya-González et al.[18] EU / 2014-18/ EL	156	M (a)	U14 (13-14)	2 (-)	35064	31236	3828	84	61	23	2.4	2	6	23	7
		M (b)	U16 (15-16)	2 (-)	40300	35475	4825	111	67	44	2.8	1.9	9.1		
		M (c)	U19 (17-19)	2 (-)	49679	45318	4361	142	94	48	2.9	2.1	11		
		M (T)	U19 (13-19)	6 (257)	125043	112029	13014	337	222	115	2.7	2	8.8		
Renshaw et al.[9] F EU / 2012-13 / EL	39	M (a)	U11 (U9-11)	- (68)	11259.8	8695.7	2564.1	7	6	1	0.6	0.7	0.4	25	8
		M (b)	U15 (U15)	- (17)	97325	87530	150	-	-	12	-	-	80		
		M (c)	U16 (U16)	- (17)	-	-	343.8	-	-	11	-	-	32		
		M (d)	U18 (U18)	- (20)	-	2500	-	-	15	-	-	6	-		
		M (T)	U18 (9-18)	- (181)	29346	-	-	127	-	-	4.3	-	-		
Rommers et al.[48] F EU / 2017-18 / EL	39	M	U15 (U10-15)	- (734)	129206	112745	16464	389	229	160	3	2	9.7	20	7
Schmidt-Olsen et al.[80] IT / 1984 / EL	1	M (a)	U11 (9-11)	- (497)	-	-	1139.2	-	-	3	-	-	2.6	11	5
		M (b)	U13 (12-13)	- (1554)	-	-	3737.4	-	-	15	-	-	4		
		M (c)	U16 (14-16)	- (1932)	-	-	5729.2	-	-	45	-	-	7.8		
		M (d)	U19 (17-19)	- (1292)	-	-	3543.7	-	-	37	-	-	10.4		
		F (e)	U13 (9-13)	- (361)	-	-	13043.5	-	-	7	-	-	0.5		
		F (f)	U16 (14-16)	- (732)	-	-	1943	-	-	49	-	-	25.2		
		F (g)	U19 (17-19)	- (232)	-	-	635.6	-	-	13	-	-	20.9		
		M (T)	U19 (9-19)	- (5275)	-	-	14223.6	-	-	100	-	-	7.4		

		F (T)	U19 (9-19)	- (1325)	-	-	3913	-	-	69	-	-	17.6		
Sieland et al.[45] EU / 2015-17 / EL	78	M	U19 (U12-19)	- (205)	46296.3	40434.8	6400	125	93	32	2.7	2.3	5	24	7
Söderman et al.[35] EU / 1996 / SEL	28	F	U19 (14-19)	10 (153)	11689.2	-	-	79	-	-	6.8	-	-	20	7
Soligard et al.[53] [F] Control EU / 2007 / -	32	F	U17 (13-17)	- (837)	45428	31086	14342	215	74	138	4.7	2.4	9.6	32	8
Soligard et al.[44] [F] ET / 2005-08 / EL	4	M (a)	U13 (13)	- (-)	-	-	9095	-	-	20	-	-	2.2	24	5
		M (b)	U14 (14)	- (-)	-	-	12154	-	-	45	-	-	3.7		
		M (c)	U16 (15-16)	- (-)	-	-	16945	-	-	68	-	-	4		
		M (d)	U19 (17-19)	- (-)	-	-	6028	-	-	38	-	-	6.3		
		F (e)	U13 (13)	- (-)	-	-	2601	-	-	15	-	-	5.8		
		F (f)	U14 (14)	- (-)	-	-	4576	-	-	22	-	-	4.8		
		F (g)	U16 (15-16)	- (-)	-	-	8163	-	-	29	-	-	3.6		
		F (h)	U19 (17-19)	- (-)	-	-	3036	-	-	35	-	-	11.5		
		M (T)	U19 (13-19)	- (-)	-	-	44222	-	-	171	-	-	5.8		
		F (T)	U19 (13-19)	- (-)	-	-	18376	-	-	101	-	-	5.5		
Sprouse et al.[49] [F] EU / 2012-20 / EL	312	M (a)	U15 (U15)	- (-)	7958	7159	799	56	23	33	7	3.2	41.3	22	7
		M (b)	U16 (U16)	- (-)	9911	8435	1476	106	44	62	10.7	5.2	42		
		M (c)	U17 (U17)	- (-)	8702	6771	1931	65	20	45	7.5	2.9	23.3		
		M (d)	U18 (U18)	- (-)	6504	5332	1172	43	21	22	6.6	3.9	18.8		
		M (e)	U19 (U19)	- (-)	10689	9055	1634	49	25	24	4.6	2.8	14.7		
		F (f)	U15 (U15)	- (-)	7852	7531	321	61	52	9	7.8	6.9	28		
		F (g)	U16 (U16)	- (-)	7612	6633	979	48	28	20	6.3	4.2	20.4		
		F (h)	U17 (U17)	- (-)	15146	13651	1495	100	46	54	6.6	3.4	36.1		
		F (i)	U19 (U18-19)	- (-)	20541	18347	2194	117	67	50	5.7	3.6	22.8		
		M (T)	U19 (U15-19)	8 (-)	43764	36752	7012	319	133	186	7.3	3.6	26.5		
		F (T)	U19 (U15-19)	9 (-)	51151	46162	4989	326	193	133	6.4	4.2	26.7		
Steffen et al.[81] [F] Control EU / 2005 / -	32	F	U17 (13-17)	51 (947)	65725	-	-	241	-	-	3.7	-	-	29	7
Tears et al.[17] [F]	234	M	U18 (11-18)	- (-)	352800	-	-	778	-	-	2.2	-	-	25	6

EU / 2009-15 / EL															
van der Sluis et al.[10] [F] EU / 2002-07 / EL	117	M	U13 (-)	- (26)	33628.9	-	-	108	-	-	3.2	-	-	22	6
Waldén et al.[82] [F] EC / 2005 / EL	2	M	U19 (U19)	8 (144)	1394	899	495	17	2	15	13.4	2.9	30.4	25	6
Wik et al.[50] [F] AS / 2016-20 / EL	144	M (a)	U13 (U13)	- (-)	17072	15094	1978	133	91	42	7.8	6	21.2	28	7
		M (b)	U14 (U14)	- (-)	19245	16726	2519	164	105	59	8.5	6.3	23.4		
		M (c)	U15 (U15)	- (-)	17865	14803	3062	194	109	85	10.9	7.4	27.8		
		M (d)	U16 (U16)	- (-)	15719	12903	2816	215	114	101	13.7	8.8	35.9		
		M (e)	U17 (U17)	- (-)	13738	11203	2535	234	123	111	17	11	43.8		
		M (f)	U18 (U18)	- (-)	9188	7340	1848	171	97	74	18.6	13.2	40		
		M (T)	U18 (U12-18)	- (301)	92827	78069	14758	1111	639	472	12	8.2	32		
Zarei et al.[83] [F] Control AS / 2017 / EL	39	M	U14 (7-14)	17 (519)	32113	29716	2397	60	36	24	1.9	1.2	10	31	7

[F] Study was implemented according to the 2006 consensus statement for epidemiological studies in football.

(a);(b);(c): indicate different cohorts in the same study; (T) indicate the total sample of the study.

EL: Elite; SEL: Sub-elite; MI: Mixed (elite and sub-elite); M: Male; F: Female; U: Under.

EU: Europe; NA: North America; SA: South America; AS: Asia; AF: Africa; OC: Oceania; EC: European Championship; ET: European Tournament; IT: International Tournament; WC: World Championship.

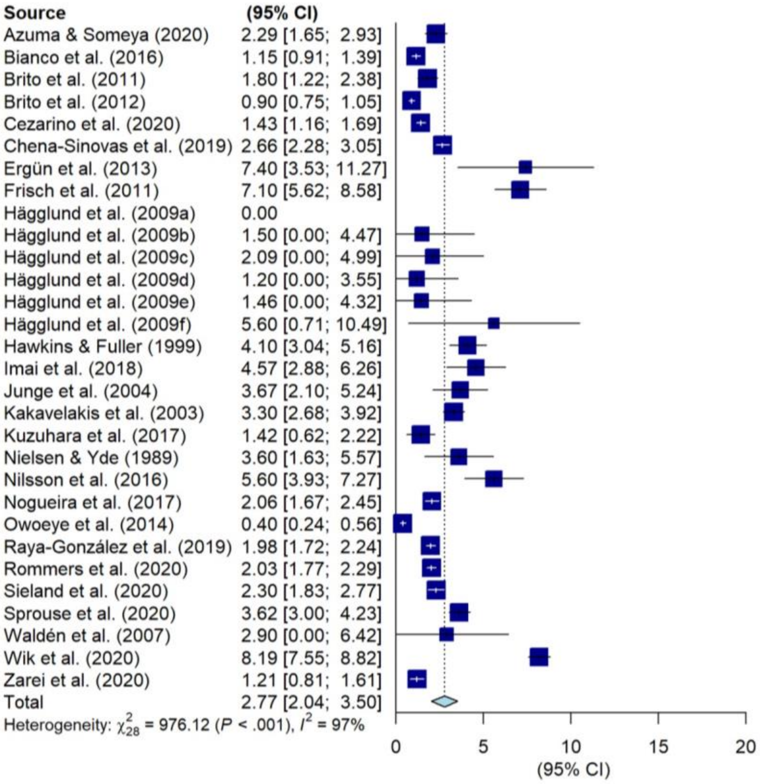

Figure 2 Training injury incidence in male youth football players with 95% confidence intervals.

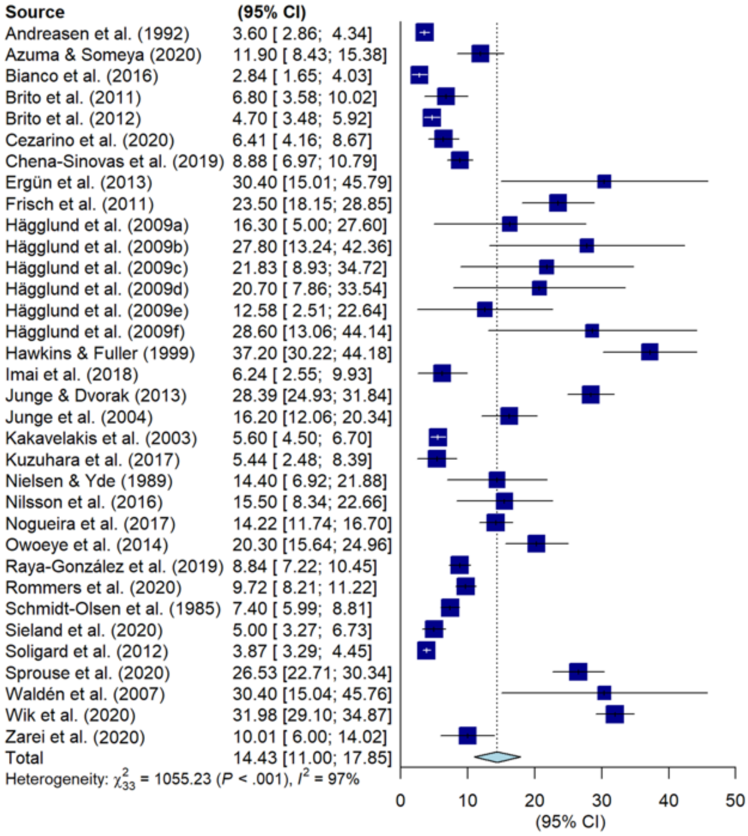

Figure 3 Match injury incidence in male youth football players with 95% confidence intervals.

Females

Nine studies (11 cohorts) reporting overall IIR,[26,27,35,43,49,51,53,73,81] 5 studies (7 cohorts) reporting training IIR[27,43,49,51,53] and 10 studies (12 cohorts) reporting match IIR[19,27,43,44,49,51,53,72,74,80] in female youth football players were included in this meta-analysis, comprising a total of n = 2179 injuries and around 9600 different players. The random effect models showed an overall IIR of 6.8 injuries/1000h (95%CI = 5.0-8.5, I^2 = 94%, quality of evidence = low), a training IIR of 2.6 injuries/1000h (95%CI = 1.2-4.1, I^2 = 90%, quality of evidence = low) and a match IIR of 15.0 injuries/1000h (95%CI = 9.7-20.2, I^2 = 96%, quality of evidence = low). Figures 4-5 display the forest plots with the training and match IIR of the analysed studies.

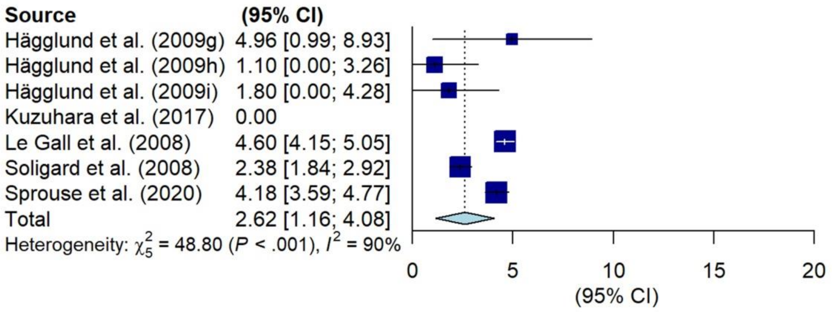

Figure 4 Training injury incidence in female youth football players with 95% confidence intervals.

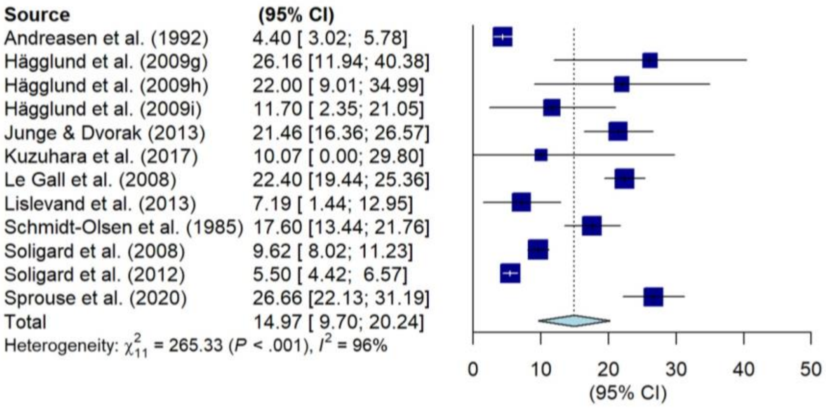

Figure 5 Match injury incidence in female youth football players with 95% confidence intervals.

3.2.2. Location of injury

Males

Twenty-four studies reported injury location and lower extremities region categories in males according to Fuller et al.[41].[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 (4.1/1000h, 95%CI = 2.9-5.2, I^2 = 99.5%) compared to the other body regions. Upper limbs was the second most commonly injured region (0.3/1000h, 95%CI = 0.2-0.4, I^2 = 94.7%), trunk was the third most commonly injured region (0.3/1000h, 95%CI = 0.2-0.3, I^2 = 92.9%) and head and neck injuries had the lowest IIRs (0.1/1000h, 95%CI = 0.0-0.1, I^2 = 88.5%). Regarding lower extremity injuries, thigh showed the highest IIR (1.2, 95%CI = 0.7-1.7, I^2 = 99.1%), followed by ankle (0.9, 95%CI = 0.6-1.2, I^2 = 97.6%), knee (0.7, 95%CI = 0.5-1.0, I^2 = 96.6%), hip/groin (0.7, 95%CI = 0.5-1.0, I^2 = 98.1%), lower leg/Achilles tendon (0.4, 95%CI = 0.2-0.5, I^2 = 94.4%), and foot/toe (0.3, 95%CI = 0.2-0.4, I^2 = 94.9%).

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 the one showed in males, with lower extremities having the highest IIR (6.5/1000h, 95%CI = 4.7-8.4, I^2 = 91.4%), followed by trunk (0.7/1000h, 95%CI = 0.5-0.8, I^2 = 0%), upper limbs (0.3/1000h, 95%CI = 0.1-0.4, I^2 = 51.0%), and with the lowest IIR head and neck injuries (0.1/1000h, 95%CI = 0.0-0.3, I^2 = 68.2%). With regards to lower extremity injuries, ankle (1.5, 95%CI = 1.2-1.9, I^2 = 64.0%) and knee (1.5, 95%CI = 0.9-2.1, I^2 = 89.3%) showed the highest IIRs, followed by thigh (1.1, 95%CI = 0.5-1.6, I^2 = 91.0%), lower leg/Achilles tendon (0.7, 95%CI = 0.3-1.1, I^2 = 90.2%), hip/groin (0.6, 95%CI = 0.2-1.0, I^2 = 91.9%), and foot/toe (0.4, 95%CI = 0.3-0.5, I^2 = 0%) (Figure 6).

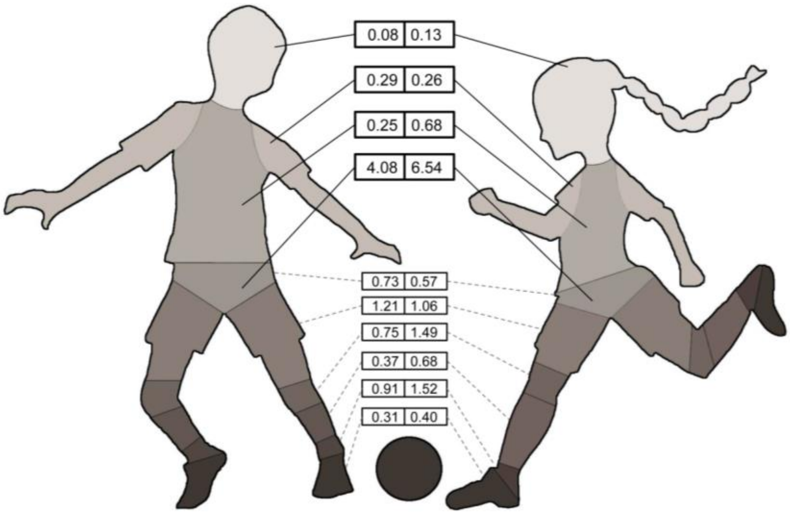

Figure 6 Location of injury in male (left side) and female (right side) youth football players. The upper boxes (solid lines) represent the incidence of injury for main groups, whereas the lower boxes (dashed lines) represent the incidence of injury for lower extremities categories.

3.2.3. Type of injury

Males

Fifteen studies reported type of injury in 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 (1.9, 95%CI = 1.3-2.6, I^2 = 99.0%), followed by joint (non-bone) and ligament (1.0, 95%CI = 0.6-1.3, I^2 = 97.4%), and contusions (0.8, 95%CI = 0.4-1.3, I^2 = 99.3%). Fracture and bone stress (0.4, 95%CI = 0.0-0.8, I^2 = 99.7%), undefined/other (0.3, 95%CI = 0.0-0.5, I^2 = 99.5%), central/peripheral nervous system (0.06, 95%CI = 0.0-0.1, I^2 = 95.6%), and laceration and skin lesions (0.03, 95%CI = 0.0-0.1, I^2 = 66.0%) were the least common types of injury.

Females

Only 3 studies were pooled in the meta-analysis.[27,35,43] Unlike male, joint (non-bone) and ligament injuries (2.4, 95%CI = 1.6-3.1, I^2 = 59.0%) were the most common type of injury, followed by muscle and tendon injuries (2.0, 95%CI = 1.7-2.3, I^2 = 0%), contusions (0.9, 95%CI = 0.6-1.2, I^2 = 44.6%), undefined/other (0.8, 95%CI = 0.5-1.2, I^2 = 57.0%), and fracture and bone stress injuries (0.3, 95%CI = 0.2-0.4, I^2 = 0%). No laceration and 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 (1.9/1000h, 95%CI = 1.1-2.6, I^2 = 99.8%) were the most usual injuries, followed by moderate (1.7/1000h, 95%CI = 1.3-2.2, I^2 = 98.0%), mild (1.1/1000h, 95%CI = 0.8-1.5, I^2 = 98.5%) and severe (0.8/1000h, 95%CI = 0.6-1.0, I^2 = 96.4%) injuries. Additionally, a total of eleven studies[9,18,23–25,31–34,46,83] reported an average of 15.5 days lost per injury in male footballers and an overall injury burden of 96.5 injury days/1000h of football exposure (95%CI = 49.9-143.1, I^2 = 100%).

Females

Only 3 studies (5 cohorts) reported severity in females.[19,51,53] Minimal injuries (3.6/1000h, 95%CI = 0.7-6.5, I^2 = 82.3%) were also the most usual injuries in females, followed by moderate injuries (1.5/1000h, 95%CI = 1.2-1.9, I^2 = 0%), severe injuries (1.3/1000h, 95%CI = 0.6-1.9, I^2 = 43.1%) and mild injuries (0.8/1000h, 95%CI = 0.5-1.0, I^2 = 0%). The paucity of data prevented the calculation of pooled estimates for the injury burden.

3.2.5. Mechanism of injury

Males

Sixteen studies (19 cohorts) were involved in the meta-analysis to compare overuse injuries versus traumatic (acute) injuries in males.[9,18,20,21,23,25,31–33,49–51,54,56,79,82] The IIR in traumatic (5.5, 95%CI = 4.0-7.0) was higher than in overuse injuries (1.1, 95%CI = 0.7-1.5). In relation with mechanism of injury, 15 studies (18 cohorts) reported data to compare contact versus non-contact injuries in males [9,21,25,31–33,45,47,49–51,55,56,79,82]. Males showed a slightly higher IIR of non-contact (3.5, 95%CI = 2.3-4.6) than contact injuries (2.8, 95%CI = 1.9-3.6).

Females

Eight studies (9 cohorts) were involved in the meta-analysis to compare overuse injuries versus traumatic injuries in females.[19,26,27,35,49,51,53,81] Similar to males, the IIR in traumatic injuries (4.5, 95%CI = 3.7-5.4) was higher than in overuse (1.6, 95%CI = 0.8-2.3) in females. Four studies (5 cohorts) reported data to compare contact versus non-contact injuries in females [49,51,53,81]. Similar IIR for non-contact (2.4, 95%CI = 1.8-3.0) and contact injuries (1.9, 95%CI = 1.7-2.2) was found.

3.2.6. New vs. recurrent injuries

Males

Eleven studies (14 cohorts) were included in an analysis aimed at comparing the IIR of new versus recurrent injuries in males.[9,24,25,31–34,48,50,51,56] The IIR of new (5.9, 95%CI = 3.9-7.8) was higher than recurrent injuries (0.8, 95%CI = 0.4-1.3).

Females

Five studies (6 cohorts) compared the IIR of new versus recurrent injuries in females.[26,27,35,51,81] Similar to males, the IIR of new injuries (5.1, 95%CI = 3.6-6.6) was higher than recurrent (1.4, 95%CI = 0.3-2.5) in female footballers.

3.2.7. Age groups

Males

Concerning the football players’ age, studies were gathered in 3 groups: U12 and below, U13-U16 and U17-U19. In males, a total of 20 studies (58 cohorts) was included to compare overall IIR,[9,18,21–25,31,33,43,46,49–51,54–56,77,78,82] 16 studies (46 cohorts) and 19 studies (55 cohorts) to compare training[9,18,21,22,24,25,31,43,49–51,54,56,77,78,82] and match[9,18,21,22,24,25,31,43,44,49–51,54,56,74,77,78,80,82] IIRs, respectively. U17-U19 male age group showed the highest overall IIR (7.5/1000h, 95%CI = 5.6-9.5, I^2 = 97%), followed by U13-U16 male (5.3/1000h, 95%CI = 3.7-7.0, I^2 = 98%), and U12 male (1.6/1000h, 95%CI = 0.8-2.4, I^2 = 85%) age groups. In particular, the mean IIRs in training decreased from U17-U19 (3.5/1000h, 95%CI = 2.1-4.9, I^2 = 91%) to U13-U16 (3.4/1000h, 95%CI = 2.2-4.6, I^2 = 95%), and U12 age groups (1.1/1000h, 95%CI = 0.4-1.7, I^2 = 72%). In match, the IIRs per age group were, in descending order: U17-U19 (20.0/1000h, 95%CI = 15.5-24.6, I^2 = 93%), U13-U16 (13.7/1000h, 95%CI = 8.5-18.9, I^2 = 95%), and U12 (2.6/1000h, 95%CI = 0.6-4.6, I^2 = 77%).

Females

Only 2 studies (5 cohorts) were included to compare overall and training IIRs,[49,51] and 6 studies (15 cohorts) to compare match IIR.[19,44,49,51,74,80] U17-U19 female age group showed an overall IIR of 6.2/1000h (95%CI = 4.7-7.8, I^2 = 38%), a training IIR of 3.1/1000h (95%CI = 2.2-4.0, I^2 = 40%) and a match IIR of 20.9/1000h (95%CI = 14.3-27.6, I^2 = 78%). U13-U16 female age group reported a match IIR of 12.7 injuries/1000h (95%CI = 5.4-19.9, I^2 = 89%). The scarcity of studies reporting overall, training and match injury IIRs in the female U12 and below group, and overall and training IIRs in the U13-U16 prevented further sub-analyses for these age 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 IIR,[21,25,32–34,43,47,54,75,76] 9 studies reported training IIR[21,25,32–34,43,47,54,75] and 9 studies reported match IIR[21,25,32–34,43,47,54,75] in sub-elite players. The random effect models showed an overall IIR of 4.8 injuries/1000h (95%CI = 2.6-6.9, I^2 = 98%), a training IIR of 2.8 injuries/1000h (95%CI = 1.4-4.3, I^2 = 96%) and a match IIR of 10.6 injuries/1000h (95%CI = 6.0-15.3, I^2 = 93%).

For its part, 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 competition.[18,20,22,24,31,44,45,48–51,56,74,79,82,83] The random effect models showed an overall IIR of 6.2 injuries/1000h (95%CI = 4.6-7.8, I^2 = 99%), a training IIR of 2.7 injuries/1000h (95%CI = 1.6-3.7, I^2 = 98.0%) and a match IIR of 17.9 injuries/1000h (95%CI = 13.0-22.8, I^2 = 98%).

Females

Three studies (4 cohorts) reported overall IIR[26,35,43], with the random effect models displaying a total of 7.9 injuries/1000h of football exposure (95%CI = 3.3-12.4, I^2 = 78%). Not enough 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 6.5 injuries/1000h (95%CI = 5.8-7.2, I^2 = 50%), 3.2 injuries/1000h of training (95%CI = 1.6-4.9, I^2 = 79%) and 18.1 injuries/1000h of match (95%CI = 9.4-26.8, I^2 = 98%).

3.2.9. Probability of Injury

The overall injury probability over one 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 lowest for U12 (7% in males and 18% in females) and U13-U16 (39% and 30% for males and females, respectively) age groups. Supplementary Material 11 provides a descriptive summary of the probabilities of injury by individual studies in both male and female cohorts.

4. Discussion

Both the methodology and statistical analyses used in the current study were identical to those in the systematic reviews and meta-analyses conducted by Lopez-Valenciano et al.[60,84] in adult men (elite players) and women (sub-elite and elite players) football players and hence, comparisons in injury profile are possible. However, these injury profile comparisons between youth and adult footballers 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 of the current study indicate that the overall, training and match IIRs in male (5.7, 2.8 and 14.4 injuries/1000h of overall, training and match exposure, respectively) and female (6.8, 2.6 and 15.0 injuries/1000h of overall, training and match exposure, respectively) youth football players are higher than the IIRs provided by previous studies in other youth team sports such as: handball (2.9, 0.9 and 9.9 injuries/1000h of overall, training and match exposure, respectively),[85] basketball (1.3, 0.5, 11.2 injuries/1000h of overall, training and match exposure, respectively)[86] and volleyball (2.4 injuries/1000h of match exposure).[87] Furthermore, the probability of youth football players sustaining a time-loss injury during a season was 47% for male and 43% for female players. These probability of injury scores are higher than the 28% reported for child and adolescent rugby players involved in a rugby season.[69] The high IIRs and probability scores found for youth footballers in the present meta-analysis reinforce the need for implementing targeted injury risk mitigation strategies in youth football.

In line with adult football players[60,84] and other youth team sports (independent of the sex of the players) such as handball,[85] basketball,[86] volleyball,[87] and rugby,[69] match IIR is always significantly higher than training. A number of studies have attributed these differences in IIRs between match and training to several factors, including: the higher physical playing demands during matches in comparison with 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 accounted for during matches, and the fatigue generated during the course of the match.[38,88,89]

4.2. Location and type of injuries

Similar to what has been reported in adult footballers, lower extremity injuries had the highest IIRs compared to the other body regions in both male and female youth football players (3.8 and 6.5 injuries/1000h for males and females, respectively).

The location of the most frequently reported injuries in male and female youth footballers was slightly different. In male players the thigh (1.2/1000h) and ankle (0.9/1000h) were the anatomical regions where injuries occurred most whereas the knee (1.5/1000h) and ankle (1.5/1000h) were the regions most frequently injured in females. These higher knee and ankle IIRs documented in female youth football players may be explained by the fact that females sustain twice as many joint (non-bone) and ligament injuries than their male counterparts (2.4 [females] vs 1.0 [males] injuries/1000h). This higher susceptibility for sustaining joint and ligament injuries observed in youth female 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) to explain why female athletes are more prone to suffer more joint (non-bone) and ligament injuries, mainly around knee and ankle joints. Due to the lack of epidemiological studies reporting IIRs in youth footballers separately for joints (non-bone) and ligaments (e.g., anterior cruciate ligament [ACL] of the knee, anterior inferior tibiofibular ligament of the ankle) a sub-analysis aimed at identifying the most 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, independently of the sex of the players.[8,18,27,35]

Unlike females, the area most frequently injured in male football players was the thigh. However, no sex-related differences were found in the magnitude of thigh IIR (~1.1/1000h 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 (~2/1000h). The link between these two 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 (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. By contrast, it should also be highlighted in this regard the fact that, in adult football, men and women did not report similar muscle injury rates. In particular, male footballers presented muscle IIRs that were twice as high as women (4.6 vs. 1.8 injuries/1000h), which might be attributed to the larger inter-sex differences in physical match demands (e.g., number of high intensity actions performed) that are evident in elite football.[92]

Interestingly, the IIRs of trunk injuries were more than twice as high for female as for male footballers (0.7 vs. 0.3 injuries/1000h), but still relatively low for both sexes. A more erect posture during landing has been evidenced in females, which could overload not only lower limbs but also trunk areas[90] and, consequently, this may increase the risk of trunk injuries (e.g., spondylolisthesis). Therefore, it would be advisable that prevention programs in females also focus on core strength. Despite head injuries that the involve nervous system (i.e., concussions and traumatic brain injuries) also receiving particular attention from current international research, our results showed the lowest IIRs for head and neck (0.1/1000h) as well as for central/peripheral nervous system (> 0.1/1000h) injury groups in both males and females, matching the findings of previous large-scale investigations.[93,94] However, these injuries might be frequently underdiagnosed due to inconsistencies in the interpretation of their symptoms and reporting[95] and thus, the use of a time-loss injury definition might have reduced the proportion of concussion injuries pooled in this research. Future prospective studies using more accurate injury definition, recognition and reporting would be needed to increase the evidence on incidence of concussions in youth football.

4.3. Severity and mechanism of injuries

Although injuries occur frequently in youth football players, fortunately the majority appear to be of minimal (1–3 days lost) severity. However, it should be highlighted that moderate (1.7 [males] and 1.5 [females] injuries/1000h) and mainly severe (0.8 [males] and 1.3 [females] injuries/1000h) IIRs found in this meta-analysis for both sexes may be considered problematic. In practical terms, it might imply that in a typical youth football squad comprised of 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 this study have revealed that a great proportion of injuries in male and female youth football might have a traumatic and non-contact mechanism, and as such they could be regarded as preventable. The implementation of comprehensive injury prevention programs aimed at improving movement competency and physical fitness in youth football have demonstrated to be a successful approach to reducing the number of moderate and severe non-contact injuries in children and adolescents.[53,96] In this sense, previous studies have demonstrated that 10–15 min of neuromuscular training activities 2 to 3 times weekly is sufficient in reducing non-contact injuries by 45% in youth football players.[97]

While injury at adult levels can have negative effects on the team and its success rate,[98] the impact of injury on development within youth football is 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 short-term tactical, technical and physical performance but also impair the long-term athlete development, health outcomes and future career opportunities.[12,99] As previous studies have only reported IIRs and 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 to build a risk matrix. The risk matrix would have helped to identify the importance (i.e., burden) of each football-related injury and may provide information to help prioritise injury prevention measures used in applied football environments. However, and based on the findings shown in previous studies,[46,100] the most burdensome injuries in youth football may be quadriceps and hamstring muscle injuries and knee ligament injuries (ACL tears), alongside growth related injuries (Osgood-Schlatter and Sinding-Larsen diseases). This injury pattern in terms of severity and mechanism of injury described for youth players is very similar to the one reported by Lopez-Valenciano et al.[60,84] for adult footballers.

4.4. New vs. recurrent injuries

As expected, and similar to what has been reported in adult football players,[60,84] recurrent IIR in youth football is lower than the new IIR (0.8 [males] and 1.4 [females], vs. 5.9 [males] and 5.1 [females] injuries/1000h, respectively). Likewise, there are no sex-related differences in new and recurrent injuries either in youth nor in adult football players. However, it should be highlighted that the ratio of new versus recurrent injuries is higher in youth players (7.4 [male youth] vs. 5.4 [male adult][60], and 3.6 [female youth] vs. 2.6 [female adult][84]).

On the one hand, the lower recurrent IIR in youth players in comparison with their adult counterparts may indicate that at young ages there is not such a 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 a larger experience in football play, adult footballers may present a higher likelihood of having suffered previous injuries compared with their youth players and hence, they may be at a higher risk of injury recurrence.[105,106] This circumstance has led some researchers to suggest that another main purpose of the injury risk mitigation strategies that should be implemented in youth football should be to delay as much as possible the appearance of the first injury event.[105,107] Longitudinal studies tracking IIR through the academy setting and into professional environments might help to elucidate if there is a consequence of repeated IIR during growth and maturation.[108]

4.5. Age groups

Results from the different age groups, representing different periods of childhood and adolescence, suggest potential interactions between maturity, sex, training and competition with IIR. In males overall incidences increased between players who are likely to be pre-pubertal (U12), circa-pubertal (U13-U16) and post pubertal (U17-U19),[109] with overall IIRs of 1.6, 5.3 and 7.5 respectively. This was driven by a high match IIRs that increased by approximately 10 injuries between each consecutive age interval (2.6 vs. 13.7 vs. 20.0). The changing profile of IIR is likely attributable to both maturation effects and increasing demands of training and competition in older age groups. Young children have an immature neuromuscular and metabolic system, with a lower muscle mass, more compliant muscle-tendon structures, and being less able to recruit fast twitch fibres, with an underdeveloped anaerobic system and with a greater reliance on aerobic metabolism.[110] All these factors will mean that immature players will work less explosively, generating and having to tolerate lower levels of force, exposing themselves to lower levels of risk, while they will also experience lower levels of fatigue during intermittent work and will able to recover from fatigue more quickly.[111] This is reflected in the U12 players having a low overall and low match IIR. Adolescent players will experience a period of rapid physical development that will result in gains in both size and fitness, but this period can be accompanied with temporarily disrupted motor co-ordination.[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 abhorrent movement mechanics while also being more susceptible to growth and overuse injuries,[8,10,113] and having a reduced ability to recover between matches,[114] likely contributing to a greater IIR compared to prepubertal players.

Players will continue to physically develop into late adolescence and early adulthood and will likely continue to increase their abilities to work at a high intensity, 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 will mean 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 large increase in training load as they begin to train on full-time professional contracts,[8] with spikes in workload suggested to contribute to injuries in 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, 3.7 and 36.0 injuries/1000h of overall, training and match exposure, respectively.

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

4.6. Level of play

The findings of this study also indicate that elite (high-level) male players present higher match IIR (17.9) than their sub-elite (less skilled) peers (10.6). These observed differences according to the level of play may be partially explained by the fact that elite players may perform more high-intensity actions during competitions and, as it has been mentioned before, this would potentially increase their risk of sustaining an injury. In addition, players skilled at 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, apart from playing with their respective teams, highly skilled young players are often required to play up age groups and compete in teams of older players. This scenario not only forces these 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 hours), which may overload their immature musculoskeletal system and thus, significantly increase their risk of injury.[118] In this sense, 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 development cycles.[120,121] Elite young football players who strive to be professional players may also be exposed to high levels of pressure.

On the other hand, 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 compared to their sub-elite peers, including better equipment, comprehensive medical support and expert coaches to control match/training loads, which may have contributed to the reduction of injury risk despite their expected greater exposure to training.[17]

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

4.7. Level and quality of the evidence

The pooled results of more than 25 epidemiological studies provided a moderate quality of evidence that supports the overall, training and match IIRs estimated for male youth football players in this systematic review and meta-analysis. On the contrary, the quality of evidence for overall, training and match IIRs in females was low, coming from only 5 (training) to 10 (match) studies. Furthermore, several of these studies were carried out in female players who were selected to participate in different tournaments,[19,44,51,72,74,80] which represents a shorter period of time compared to data collected from an entire football season. Therefore, future research should be focused on monitoring IIRs in female youth football players throughout competitive seasons for a broader comparison with the incidences documented in males.

4.8. Limitations

Although this novel study was conducted following the international guidelines for systematic reviews and meta-analyses, some limitations should be acknowledged. Variations in injury definition and data collection procedures used in the different studies might partly explain the heterogeneous estimates obtained in our main meta-analysis, like in previous meta-analysis conducted in Sport Medicine.[28,60,69,84] To mitigate this, only those studies that rigorously and clearly followed the time-loss injury definition described by Fuller et al.[41] and Hägglund et al.[42] were included in the sub-analyses. Surely, the additional inclusion of medical attention injuries might have led to a higher IIR. However, this could also intensify the differences between data collection procedures since non-time loss IIR has been shown to be especially sensitive to different recording settings, and a research-invested clinical recorder might report almost 9 times greater incidence compared to other non-involved recorders (i.e., non-involved physiotherapists).[122] Thus, and based on the reality of injury surveillance in 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, time-loss definition was used. Furthermore, when different epidemiological data were presented (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 such as differences existing between the geographic areas (or time of year) regarding the 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 studies reporting the location and type of injuries for elite and sub-elite players by sex made further sub-analyses to identify potential for differences regarding the level of play impossible. However, and based on previous results for 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, albeit another important focus would have been the estimation of physical maturation status and the influence of the growth spurt on IIR, as well as the incidence of growth-related injuries in young players, the sample size of studies included was also not sufficient to investigate interactive effects within these factors.

5. Conclusions

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

Acknowledgments

The authors would like to thank all the researchers who provided additional information. Part of this work was carried out during a research stay at Cardiff Metropolitan University from March to July 2020. Francisco Javier Robles-Palazón was supported by the Program of Human Resources Formation for Science and Technology (20326/FPI/2017) from the Seneca Foundation-Agency for Science and Technology in the Region of Murcia (Spain). Francisco Ayala was supported by a Ramón y Cajal postdoctoral fellowship given by the Spanish Ministry of Science and Innovation (RYC2019-028383-I). This study is part of the project entitled “Estudio del riesgo de lesión en jóvenes deportistas a través de redes de inteligencia artificial”, funded by the Spanish Ministry of Science and Innovation (DEP2017-88775-P), the State Research Agency (AEI) and the European Regional Development Fund (ERDF). The funders had no role in study design, data analysis, interpretation, or the decision to submit the work for publication.

Author’s contributions

FJR-P, AL-V, 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. AG-G 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.

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