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SYSTEMATIC REVIEW

Injury Incidence, Prevalence and Severity in High-Level Male Youth Football: A Systematic Review

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Abstract

Background At a young age, high-level youth footballers enter structured practice where they engage in regular training and matches. The academy system is considered fundamental to a young footballer's tactical, technical and physical development. Yet, with regular training and matches, high-level youth footballers may be exposed to the risk of injury.

Objective This systematic review analyses and summarises published scientific information on high-level youth football injury characteristics and calculates the risk of them sustaining an injury over the course of a typical season.

Methods The search was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Of the 1346 studies found, 23 fulfilled the inclusion criteria.

Results Quality assurance scores for the selected research articles ranged between two and five out of eight. A high degree of heterogeneity between studies was observed. The probability of sustaining a time-loss injury during a high-level youth season ranged between < 1% and 96% for under 9- to under 16-year age groups and 50% and 91% for under 18- to under 21-year age groups. Pooled estimates for total (training and match) incidence per 1000 h was 5.8 for youth players aged under 9 to under 21 years, 7.9 for older players (under 17–under 21 years) and 3.7 for younger aged players (under 9–under 16 years). Training injury incidence rate ranged from 0.69 to 7.9 per 1000 h for all age groups in youth football. Match injury incidence rate for high-level youth players ranged from 0.4 to 80.0 per 1000 h. Close to one-fifth (18%) of all high-level youth football injuries were classified as severe and required > 28 days recovery time. Muscle strain injury accounted for 37% of all injuries reported in youth football. High probabilities (> 90%) of sustaining a time-loss injury over one typical high-level football season were found.

Conclusion High-level youth players lose large portions of the seasonal development to injury, with players seemingly suffering long absences from training and matches, consequently affecting health and well-being and possibly burdening club/parental finances and healthcare systems.

Key Points

Studies reviewed show a high probability of sustaining a time-loss injury during a typical high-level youth football season. High-level youth players seemingly lose large portions of seasonal development time to injury.

Pooled estimates for total incidence per 1000 h were 7.9 for youth players aged under 17 to under 21 years, 3.7 for under 9 to under 16 years, and 5.8 for players aged under 9 to under 21 years.

Nearly one-fifth (18%) of all reported injuries were classified as severe, requiring > 28 days recovery time, with muscle strain injury accounting for 37% of all injuries sustained in high-level youth football.

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1 Introduction

Football clubs worldwide have academy structures for the development of talented young players. The aim of academy football is to prepare these selected children through organised practice and competition for senior football. Talented footballers enter academies at a young age. In England and Wales there are approximately 12,500 footballers aged between 8 and 22 years who are registered with professional youth development departments (academies) of professional clubs [1]. For under 18-year and under 23-year age groups, football season spans over 9 months per year with a predefined number of League matches to fulfil. At younger age groups (from under 9-year up to under 15-year age groups), to promote player development, the match format is different and scaled to suit the level of player maturation and physical development with reduced match duration, smaller pitch sizes and reduced player numbers. Differences between under 15-year to under 18-year age groups differ only by duration of match. Availability to train and gain match exposure and experience are likely essential for high-level youth footballers to develop physically, and to improve technical and tactical skill sets necessary for senior football [2]. The high intensity activities performed during football training and matches do, however, expose players to the potential for injury [3–5]. Sustaining an injury reduces the player's availability and may also negatively influence future performance by reducing flexibility [6], strength [7], aerobic fitness [8] and repeated sprint performance [9], and impair the progress of development and future career opportunities [10–13]. These significant consequences of injuries on players' development and well-being call for a greater understanding of injury incidence, prevalence and severity in high-level youth football to help inform injury reduction programmes.

While numerous epidemiological studies have been conducted on the injury characteristics of senior male [14–18] and female footballers [19–21], high-level youth football has received less attention. An early review by Giza and Micheli [22] provided a general analysis of the literature up to 2001 in youth football. Giza and Micheli [22] reported that youth injury incidence ranged from 2.3 per 1000 training hours to 14.8 per 1000 match hours, concluding that youth football should be considered 'relatively safe'. More recently, Faude and co-workers [23] provided an update on youth football injury characteristics, reporting 10–15% of severe injuries. However, how the data were collected and how injury was defined in those studies reviewed varied considerably. In addition, data were pooled from both elite and sub-elite, male and female, tournament and league populations, making comparisons difficult [23]. Information pertaining to injury in high-level football is limited and what is available provides an unclear picture of incidence, prevalence and severity. Our aim was to present the broad spectrum of data on football injuries for male youth players considered high-level or elite and calculate the probability of sustaining a time-loss injury over one season. To date only a single systematic review exists investigating injury incidence in male high-level/elite youth football [24], which only included six articles and did not calculate pooled estimates of injury incidence per 1000 h or probability of sustaining a time-loss injury. The current systematic review expands on this work to include 17 additional studies providing an updated and more detailed report to include extensive data on injury incidence, prevalence and severity. Furthermore, this review uses published injury incidence data to calculate pooled estimates of injury incidence from studies using similar definitions.

2 Methods

We conducted a systematic review of the literature to identify relevant studies, prior to analysis of injury data. Our review was in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [25] (see PRISMA flow chart, Fig. 1).

2.1 Eligibility Criteria

We searched information sources for any primary research studies that reported data on high-level/elite football injury in youth (children 8+ years of age and adolescents under 21 years of age). Due to the limited language skills of the reviewers, non-English articles could not be included. Table 1 outlines the full inclusion criteria.

2.2 Information Sources

We searched the Academic Search Complete, CINAHL, Cochrane, Medline, PubMed, SPORTDiscus and Web of Science databases from inception up to and including May 2019. Additionally, we hand-searched for references from key reviews and prior work on high-level/elite youth football. To ensure that all relevant articles were identified, citation tracking of all included articles was performed using Google Scholar [26]. The following keywords were used for the search strategy for sport ('football' or 'soccer'), population ('male' or 'youth' or 'adolescen*' or 'young people' or 'teen' or 'young adult' or 'child*',) injury type ('injur*' or 'fracture' or 'sprain' or 'tear' or 'rupture' or 'contusion' or 'dislocation' or 'haematoma') and study design ('inciden*' or 'prevalence' or 'audit' or 'surveillance').

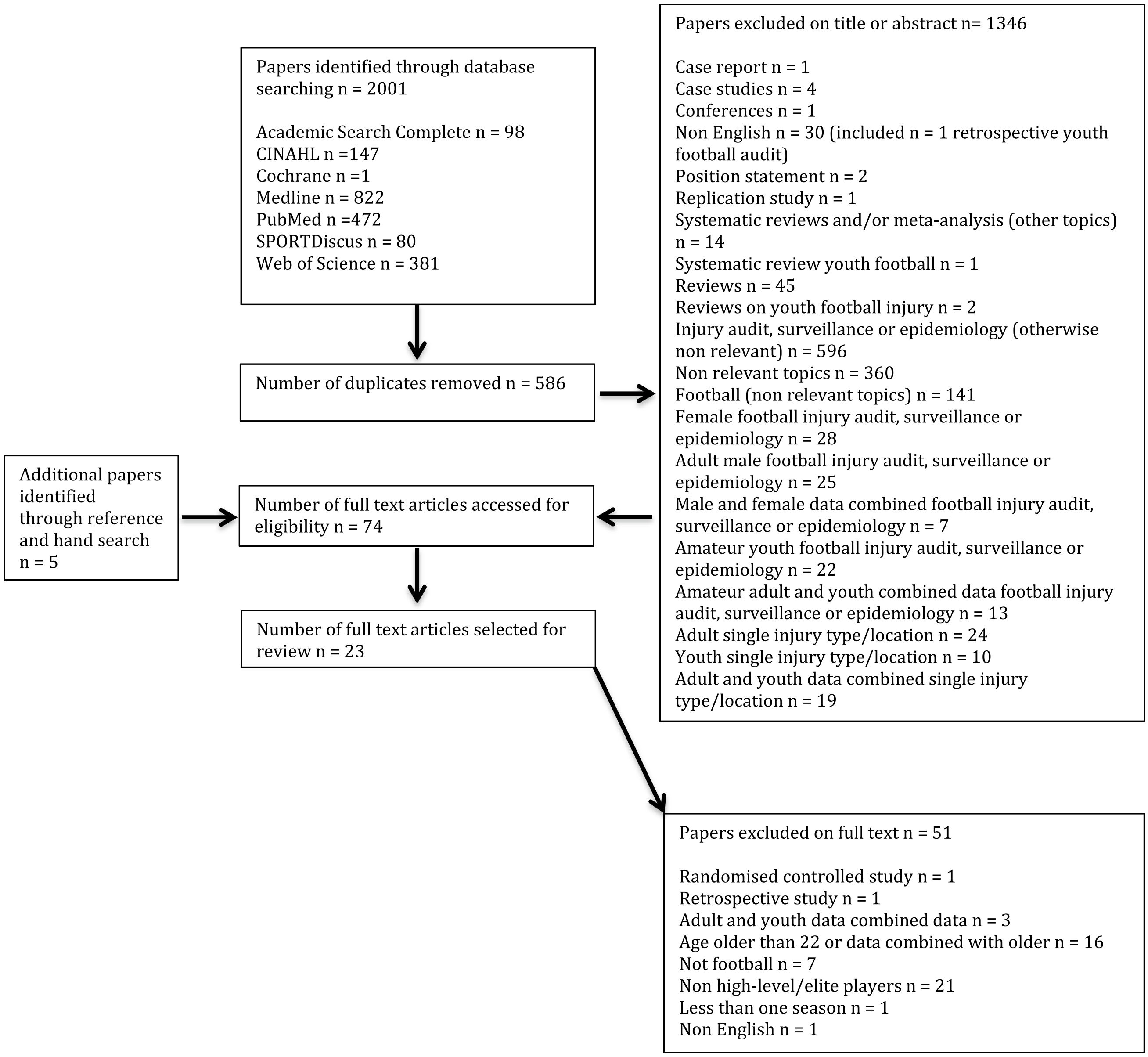

Fig. 1 PRISMA flow chart of literature retrieval and selection

2.3 Study Selection

The studies retrieved by the search were initially screened by title and abstract by one reviewer (SJ) identifying studies on high-level/elite child or youth football injury with a second reviewer (AG) double-checking studies rejected at this stage. Screening of studies evaluated as being potentially useful by title and abstract was conducted by SJ and SA collaboratively. Studies were then selected based on their potential for containing information fitting the inclusion criteria or being of further use in locating such studies for evaluation of their full text. Full text articles were then retrieved either online or via the British Library, leading to the final selection of studies for the systematic review. Selected studies were assessed by two reviewers (SJ and SA) independently for quality using the criteria outlined by Loney et al. [27] for incidence and prevalence (Table 2). This scale consisted of eight dichotomous questions; each of the eight questions was assigned a score of 1 point making eight the maximum score possible [27]. After completing the evaluation both reviewers came to a consensus for every article reviewed.

2.4 Data Collection Process

Selected studies were investigated further with respect to the study selection criteria by three reviewers (SJ, SA and AG)

Table 1 Study selection criteria

Inclusion	Exclusion
Population	*Population*
Male	Female
Children/adolescent/youth (8–21 years old)	Men (aged over 22 years)
Football/soccer player	Young child (aged below 8 years)
Elite (professional youth academy or national team) or highly skilled (based on the league of their team)	Other invasive field sports not football (e.g. rugby, Australian Rules Football, American Football, etc.)
	Individual sports (e.g. tennis, badminton, etc.)
Outcome	*Outcome*
Injury incidence per 1000 h, type, location, severity	Injuries sustained outside of training or games
Injuries sustained in either game or training	Dental injuries
Study design	*Study design*
Prospective cohort; cohort design	Retrospective design
Studies of one or more seasons	Studies less than one season
Original primary peer-reviewed studies reported findings	Conference proceedings
English language	Abstracts only
	Any review study, case report, or current concepts
	Non-English language

collaboratively. We extracted data from the final group of studies (Table 3) on the topics of incidence (SJ/SA), prevalence (SJ), severity of injury (SJ/SA), injury type (SJ/SA), nature of injury (SJ/SA), injury mechanism (SJ/SA) and injury definition (SJ/SA).

2.5 Injury Incidence, Severity, Type, Location and Mechanism

Published injury incidences in youth football for training, matches and overall exposure per 1000 h are presented with 95% confidence intervals (CI) (incidence/$e^{(1.96 \times \sqrt{(1/\text{injuries})}}$ to incidence $\times\, e^{(1.96 \times \sqrt{(1/\text{injuries})}}$) (Table 4). In Tables 5, 6, 7, 8, and 9 injury severity, type, location, mechanism and contact versus non-contact injury are presented in absolute values with percentages in parentheses.

2.6 Pooled Injury Incidence Estimates

Pooled data of overall injury incidence for high-level youth footballers was calculated where study homogeneity allowed (i.e. injury definition and reporting of injury incidence by 1000 h). We calculated these estimates by meta-analysis of log incidence rate using the metan command in Stata V14 [standard errors of log incidence rate were calculated as 1/square root (number of injuries)]. We reported the metan I^2 statistic, which varies between 0% and 100% depending on the variation in pooled injury incidence estimates due to study heterogeneity [28]. In addition, the 95% prediction interval for the pooled injury incidence rate was reported, which is a 95% range for the incidence rate that may underlie the observed rate in any given study, considering the heterogeneity between studies.

2.7 Transforming Exposure Data to Injury Probabilities

Where match injury incidence was given per 1000 h, post hoc probabilities of injury over a season were determined using the following equation:

$$P(\kappa) = \frac{(\lambda t)^{\kappa} e^{-\lambda t}}{\kappa!}, \quad \text{for } \kappa = 1,\ 2,\ 3\ldots$$

The equation shows the Poisson distribution model for youth football injury probability, where κ is the total number of injuries occurring in a squad of players and total time of match play exposure over a single season, t is the time-interval in hours, e is the base of the natural logarithm ($e = 2.71828\ldots$), $\kappa!$ is the factorial of 'κ' and λt is the injury incidence multiplied by length of exposure.

For a detailed description of the Poisson injury distribution model the reader should refer to the work of Parekh et al. [29]. The Poisson distribution for injury probability has previously been employed in rugby studies [29, 30] and can describe the frequency of injuries occurring that is assuming these injuries occur independently and take place over time or space [31]. Parekh et al. [29] found that in order to calculate injury probability incidence rate, duration and number of matches played in a single season are required. Therefore, to use Poisson distribution for injury probability it must be assumed that each player within the squad would have a

Table 2 Quality assurance scores for included studies

References	Question 1[a]	Question 2[b]	Question 3[c]	Question 4[d]	Question 5[e]	Question 6[f]	Question 7[g]	Question 8[h]	Total
Bacon and Mauger [40]	+	+		+	+			+	5
Bianco et al. [53]	+				+	+	+	+	5
Bowen et al. [41]	+			+				+	3
Brink et al. [43]	+				+			+	3
Bult et al. [44]	+	+		+	+		+		5
Deehan et al. [33]	+	+			+			+	4
Ergün et al. [54]	+							+	2
Hawkins and Fuller [42]	+			+		+		+	4
Johnson et al. [37]	+	+				+		+	4
Junge et al. [55]	+							+	2
Kemper et al. [46]	+			+	+		+	+	4
Le Gall et al. [48]	+					+		+	3
Le Gall et al. [47]	+					+		+	3
Merron et al. [34]	+			+	+			+	4
Nilson et al. [50]	+			+	+			+	4
Peterson et al. [52]	+							+	2
Price et al. [39]	+	+				+		+	4
Read et al. [35]	+	+						+	3
Renshaw and Goodwin [36]	+			+				+	3
Tears et al. [38]	+			+				+	3
Timpka et al. [51]	+	+				+		+	4
Tourny et al. [49]	+							+	2
Van der Sluis et al. [45]	+							+	2

[a]Study Design and Sampling Method: Are the study design and sampling method appropriate for the research question?

[b]Sampling Frame: Is the sampling frame appropriate?

[c]Sample Size: Is the sample size adequate?

[d]Appropriate Measurement: Are objective, suitable and standard criteria used for measurement of the health outcome?

[e]Unbiased Measurement: Is the health outcome measured in an unbiased fashion?

[f]Response Rate: Is the response rate adequate? Are the refusers described?

[g]Results: Are the estimates of prevalence or incidence given with confidence intervals and in detail by subgroup, if appropriate?

[h]Study Subjects: Are the study subjects and the setting described in detail and similar to those of interest to you?

similar risk of sustaining injury [29]. Probability calculations were based on game duration being between 40 and 90 min as per Elite Player Performance Plan (EPPP), Royal Dutch Football Association (KNVB), Fédération Francaise de Football (FFF) and Union of European Football Association (UEFA) youth regulations [32], a conservative 30 matches per season as per EPPP regulations, and injuries being independent events.

3 Results

Of the 1346 studies found via our electronic and manual searching of the databases, 23 were included in the review. Details of exclusion and reason for exclusion are provided in Fig. 1.

3.1 Study Characteristics

The range of publication dates for the selected studies was 1999–2018. Quality assurance scores for the included research studies ranged between two and five out of a possible eight (Table 2). Of the 23 studies in this review, ten were from England [33–42], four from the Netherlands [43–46], three from France [47–49], two from Sweden [50, 51], and one each from the Czech Republic [52], Italy [53] and Turkey [54]. Another study included data from the Czech Republic, France and Germany combined [55]. Overall, 17 studies [33–46, 49, 50, 53] examined professional academy youth players, with three [47, 48, 54] investigating national teams. The remaining studies collected data on highly skilled [52, 55] and elite youth players [51]. Twenty studies used a prospective cohort design, collecting data using physiotherapists, sports physicians or coaches [33–43, 45,

Table 3 Summary of studies on injury characteristics in high-level male youth football

References	Country	Study design	Duration of data collection	Injury definition	Level of player
Bacon and Mauger [40]	Great Britain	Prospective study cohort	2 seasons (2012–2014)	Not specified	Professional academy
Bianco et al. [53]	Italy	Prospective study cohort	1 season (2013–2013)	Consensus statement [55]	Professional academy
Bowen et al. [41]	Great Britain	Prospective study cohort	2 seasons (2013–2015)	Consensus statement [55]	Professional academy
Brink et al. [43]	Netherlands	Prospective study cohort	2 seasons (2006–2008)	Consensus statement [55]	Professional academy
Bult et al. [44]	Netherlands	Cohort study	1 season minimum, 3 seasons maximum 2013–2016	Consensus statement [55]	Professional academy
Deehan et al. [33]	Great Britain	Prospective study cohort	5 seasons (1999–2004)	Time loss at least 48 h	Professional academy
Ergün et al. [54]	Turkey	Prospective study cohort	3 seasons	Consensus statement [55]	National team
Hawkins and Fuller [42]	Great Britain	Prospective study cohort	1994–1997	Time loss at least 24 h	Professional academy
Johnson et al. [37]	Great Britain	Prospective study cohort	2001–2007	Not specified	Professional academy
Junge et al. [55]	Czech Republic, France, Germany	Cohort	1 year	Time loss at least 1 wk	High skill level
Kemper et al. [46]	Netherlands	Prospective study cohort	1 season (2012–2013)	Consensus statement [54]	Professional academy
Le Gall et al. [48]	France	Prospective study cohort	10 seasons (1995–2005)	Time loss at least 48 h	National team
Le Gall et al. [47]	France	Cohort study	10 seasons (1993–2003)	Time loss at least 48 h	National team
Merron et al. [34]	Great Britain	Prospective study cohort	4 seasons	Time loss at least 48 h	Professional academy
Nilson et al. [50]	Sweden	Prospective study cohort	1 season (2013–2014)	Consensus statement [54]	Professional academy
Peterson et al. [52]	Czech Republic	Prospective study cohort	1 year	Time loss at least 1 wk	High skill level
Price et al. [39]	Great Britain	Prospective study cohort	2 seasons (1999–2001)	Time loss at least 48 h	Professional academy
Read et al. [35]	Great Britain	Prospective study cohort	1 season (2014–2015)	Time loss at least 48 h	Professional academy
Renshaw and Goodwin [36]	Great Britain	Prospective study cohort	1 season (2012–2013)	Consensus statement [55]	Professional academy
Tears et al. [38]	Great Britain	Prospective study cohort	6 seasons (2009–2015)	Consensus statement [54]	Professional academy
Timpka et al. [51]	Sweden	Prospective study cohort	1 season	Medical attention and/or incomplete match and/or missing next match	Elite
Tourny et al. [49]	France	Prospective study cohort	3 seasons	Not specified	Professional academy
Van der Sluis et al. [45]	Netherlands	Prospective study cohort	2002-2007	Consensus statement	Professional academy

46, 48–54] and three studies used a cohort design [44, 47, 55]. Eight studies collected data over a single season [35, 36, 46, 50–53, 55]; the remaining studies collected data over two seasons [39–43], three seasons [44, 45, 49, 54], four seasons [34], five seasons [33], six seasons [37, 38] and ten

Table 4 Injury incidence synthesis for high-level male youth football players

References	Age (years)	Number of players	Number of injuries	Exposure (h)	Injury incidence per 1000 h			Ratio (ratio of injuries per 1000 h of matches to injuries per 100 h of training)	Game duration (min)	Average probability of injury to player in a typical season (%)
					Training	Matches	Overall			
Bacon and Mauger [40]	U18–U21	41	85	8054.4	3.72 (2.7–5.1)	5.84 (4.4–7.8)	10.55 (8.5–13.1)	1.57	90	23
Bianco et al. [53]	U13–U20	77	107	83.760	1.15 (0.9–1.4)	2.84 (18.8–4.3)	1.28 (1.0–1.6)	2.47	80–90	10–16
	U17–U20	23	35		1.13[a]	4.3[a]	1.4 (1.0–1.9)	3.81		
	U13–U16	54	72		1.16[a]	2.2[a]	1.22 (1.0–1.5)	1.9		
Bowen et al. [41]	U18–U21	32	38		7.9[a]	33.5[a]	21.1 (15.4–29.0)	4.24	90	78
Brink et al. [43]	U18	53	320	6.70	6.74[a]	26.65[a]		3.95	90	70
Bult et al. [44]	U12–U19	170	620	74,358			8.34 (7.7–9.0)		60–90	
	U19	43	93	13,475			6.90 (5.6–8.5)			
	U17	38	119	11,761			10.12 (8.5–12.1)			
	U16	53	113	13,066			8.65 (7.2–10.4)			
	U15	54	139	11,175			12.44 (10.5–14.7)			
	U14	54	84	11,332			7.41 (6.0–9.2)			
	U13	50	51	9965			5.12 (3.9–6.7)			
	U12	17	21	3583			5.86 (3.8–9.0)			
Deehan et al. [33]	U9–U19	210	658							
Ergün et al. [54]	U17–U19	52	29	2390.2	7.4[a]	30.4[a]	13.56 (9.4–19.4)	4.11	80–90	62–75
	U19	52	10	772.4	3.2[a]	53.9[a]	13.0 (7.0–24.2)	16.84	90	91
	U18	52	1	330	0[a]	15.2[a]	3.0 (0.4–21.3)	0	90	50
	U17	52	18	1287.8	11.9[a]	21.5[a]	14.0 (8.3–22.2)	1.81	80	62
Hawkins and Fuller [42]	Youth	30	166		4.1 (3.2–5.3)	37.2 (30.8–44.9)		9.07	90	81
Johnson et al. [37]	U9–U16	292	476		1.44 (1.3–1.6)	10.5 (9.0–12.2)	2.23 (2.0–2.4)	7.29	40–90	19–38
Junge et al. [55]	U14–U18	32	19	233.1			2.5 (1.6–3.9)			
		36	17	292			2 (1.4–2.8)			
		65	42	323.1			2 (1.6–2.6)			
		70	53	298.3			2.5 (2.0–3.2)			
Kemper et al. [46]	U12–U18	101	134		3.3[a]	18.82[a]	5.9 (4.9–7.0)	5.79	60–90	43–57
Le Gall et al. [48]	U14	233	588	104,850	4.7 (4.3–5.2)	11.8 (10.1–13.7)	5.6 (5.2–6.1)	2.51	80	38
Le Gall et al. [47]	U14–U16	66	1152	237,6000	3.9 (3.6–4.1)	11.2 (10.1–12.4)	4.8 (4.5–5.1)	2.87	80	36
	U16				3.8 (3.3–4.3)	14.2 (12.0–16.8)	5.2 (4.5–5.4)	3.74	80	43
	U15				3.7 (3.3–4.2)	10.4 (8.6–12.5)	4.6 (4.2–5.1)	2.81	80	34
	U14				4.1 (3.7–4.6)	9.5 (7.9–11.5)	4.9 (4.7–5.8)	2.32	80	32
Merron et al. [34]	U16–U18	112	236		6.1[a]	25[a]	8.07 (7.1–9.2)	4.1	80–90	63–68
Nilson et al. [50]	U19	43	61	10,367	5.88 (4.4–7.9)	15.5 (9.8–24.6)	6.8 (5.3–8.7)	2.64	90	50
Peterson et al. [52]	U16–U18	65	136	323.1	7.9[a]	38.4[a]	6.6 (5.6–7.8)	4.86	80–90	78.48–82
	U14–U16	70	126	301.3	7.2[a]	35[a]	6.0 (5.0–7.1)	5.53	70–80	71–75
Price et al. [39]	U9–19	4773	3805							
Read et al. [35]	U11–18	608	804							
Renshaw and Goodwin [36]	U9–U18	181	127	29,346.15	2.51 (2.0–3.2)	8.86 (6.5–12.0)	4.33 (3.6–5.2)	3.53	40–90	16–33
	U18	20	33	3013.33	6.0 (3.6–10.0)	29.0 (17.2–49.0)	11.0 (7.8–15.5)	4.83	90	73
	U16	17	24	4218.27	1.79 (0.9–3.8)	32.32 (17.4–60.1)	5.94 (3.7–9.6)	18.06	80	73
	U15	17	26	3953.13	2.89 (1.6–5.2)	80.0 (45.4–140.9)	6.84 (4.7–10.1)	27.68	80	96
	U12–U14	59	37	6930.2	3.96 (2.6–6.0)	3.57 (1.3–9.5)	5.34 (3.8–7.4)	0.9	40–80	7–13
	U9–U11	68	7	11,231.22	0.69 (0.3–1.5)	0.39 (0.1–2.8)	0.62 (0.3–1.3)	0.57	40–60	0.78–1
Tears et al. [38]	U12–U18		882	1179.86	1.5[a]	24.1[a]	2.5 (2.4–2.7)	16.07	60–90	52–66

Table 4 (continued)

References	Age (years)	Number of players	Number of injuries	Exposure (h)	Injury incidence per 1000 h			Ratio (ratio of injuries per 1000 h of matches to injuries per 100 h of training)	Game duration (min)	Average probability of injury to player in a typical season (%)
					Training	Matches	Overall			
Timpka et al. [51]	U17		16	2361			6.8 (4.2–11.1)			
	U16		9	3227			2.8 (1.5–5.4)			
	U15		6	3227			1.2 (0.5–2.7)			
Tourny et al. [49]	U20	58	618	U16-U20 477	3.8[a]	42.2[a]		11.11	90	85
	U19	51		U12-U15	2.8[a]	30.3[a]		10.82	90	74
	U17	52		368	3.6[a]	24.1[a]		6.69	80	66
	U16	52			2.2[a]	29.4[a]		13.36	80	73
	U15	51			2.8[a]	36.7[a]		13.11	80	77
	U14	57			2.3[a]	28.7[a]		12.48	80	68
	U13	53			2.2[a]	16.5[a]		7.5	60	39
	U12	38			1[a]	9.4[a]		9.4	60	25
Van der Sluis et al. [42]	U12–U14	26	108	5.46	3.84[a]	15.91[a]			60–70	43
	U14				2.80[a]	11.77[a]			70	30
	U13				1.59[a]	9.34[a]			60	24
	U12								60	

95% confidence interval are given in parentheses

U under

[a]Did not provide number of injuries for training or matches separately

seasons [47, 48]. In total, data from 71 playing seasons were analysed in our review (Table 3).

3.2 Injury Definition

In 2006 Fuller et al. [56–58] provided a consensus statement on injury definition, severity, recurrent injury, match and training exposure for future studies of football. Ten studies [36, 38, 41, 43–46, 50, 53, 54] reported using the consensus statement definition for time-loss injuries (Table 3). Six studies [33–35, 39, 47, 48] used 48 h and one [42] used 24 h. A single study [51] used medical attention, defining injury as inability to complete a match or missing a subsequent session. Two studies [52, 55] used 1 week without being able to train or play matches, while a further two studies [49, 51] did not specify the duration of time loss. Another two [37, 40] studies failed to provide any injury definition. No studies defined 'overuse injuries'; where possible we pooled injuries that could be classified as overuse or growth related [59].

3.3 Probability of Injury

Seventeen studies [34, 36–38, 40–43, 45–50, 52–54] reported match injury rates as per 1000 player hours (Table 4). The highest injury probability (96%) was found for an under 15-year age group and lowest (1%) for under 9 years [36]. The probability of the youngest (under 9- to under 13-year age groups) high-level players sustaining an injury over one season ranged from 1% to 39% [36, 49]; for under 14- to under 16-year age group footballers, the range was larger (13% to 96% [36]; and for the under 18- and under 21-year age group, 23% [40] to 85% [49]), higher than the youngest age groups.

3.4 Pooled Injury Incidence

For total exposure the calculated pooled estimate of time-loss injury to high-level youth aged under 9 to under 21 years was 5.8 (95% CI 3.4–10.0) per 1000 h [36, 38, 41, 44, 46, 50, 53, 54] (Fig. 2). Pooled data of injury incidence for high-level youth players aged under 17 to under 21 years for total exposure was 7.9 (95% CI 4.4–14.5) [36, 38, 41, 50, 53, 54] and lower for players under 9 to under 16 years at 3.7 (95% CI 1.0–13.9) [36, 44, 53] per 1000 h (Fig. 3). There was a high degree of heterogeneity between studies [28], i.e. $I^2 = 99.2\%$ (under 9 to under 21 years), 96.8% (older than under 17 years) and 99.4% (under 9 to under 16 years).

3.5 Incidence of Injury

Overall, 17 studies [34, 36–38, 40–43, 45–50, 52–54] reported injury incidence per 1000 h for both training and

Table 5 Injury severity absolute and percentage (%) as measured by inability to play or train, or length of absence from playing high-level male youth football

References	Minimal/slight	Minor/mild	Moderate	Severe/major
Bianco et al. [53]		44 (41)	52 (49)	11 (10)
Bult et al. [44]	201 (32)	116 (19)	208 (34)	95 (15)
Ergün et al. [54]	16 (55)	5 (17)	7 (24)	1 (3)
Hawkins and Fuller [42]	24 (14)	52 (31)	69 (42)	21 (13)
Le Gall et al. [47]	357[a] (31)	337 (29)	344 (30)	114 (10)
Le Gall et al. [48]	153[a] (26)	194 (33)	182 (31)	59 (10)
Merron et al. [34]		84 (34)	88 (37)	64[b] (27)
Nilssen et al. [50]	4 (7)	13 (21)	25 (41)	19 (31)
Price et al. [39]	357 (10)	868 (23)	1659 (44)	858 (23)
Read et al. [35]	118 (15)	164 (20)	345 (43)	177 (23)
Renshaw and Goodwin [36]		9 (7)	85 (67)	33 (26)
Tears et al. [38]	173 (22)	151 (19)	266 (34)	188 (24)
Tourny et al. [49]		147[c] (24)	300 (50)	159 (26)

Percentages (%) are given in parentheses

[a] 2–3 days

[b] > 29 days

[c] < 7 days

matches (Table 4). Injuries per 1000 h of total exposure were reported by 16 studies [34, 36–38, 40, 41, 44, 46–48, 50–55]. Injury incidence for all age groups sustained at training ranged from 0.69 [36] to 7.9 [41] injuries per 1000 h. When injury incidence was measured as total exposure per 1000 h, these ranged from 0.6 (CI 0.3–1.3) for under 9- to under 11-year age groups [36] to 21.1 injuries per 1000 h for under 18- to under 21-year players [41]. Eight studies gave injury incidence per 1000 h on players aged between under 18 to under 21 years [36, 40–44, 49, 50]; these ranged from 2.8 [49] to 7.9 [41] for training, 5.8 (CI 4.4–7.8) [40] to 42.2[49] for matches and 6.9 (CI 5.6–8.5) [44] to 21.1 [41] for total exposure per 1000 h. Twelve studies provided injury incidence data on high-level youth players per 1000 h on under 9- to under 18-year age groups [34, 36–38, 44–46, 49–52, 55]; for training these ranged from 0.69 (CI 0.3–1.5) [36] to 7.9 [52]. Where injury incidence was measured for matches per 1000 h, incidence rates ranged between 0.4 (CI 0.1–2.8) for under 9- to under 11-year players [36] to 38.4 for under 16- to under 18-year age groups [52]. Measuring injury incidence per 1000 h for total exposure ranged from 0.6 (CI 0.3–1.3) for under 9- to under 11-year age groups [36] to 12.4 (CI 10.5–14.7) for under 16-year players [44]. Three studies did not provide data for injury incidence in training, matches or total exposure [33, 35, 39].

3.6 Severity of Injury

Seven studies [35, 38, 39, 42, 44, 50, 54] defined minimal/slight injuries as requiring 1–3 days' recovery time (Table 5). Minimal/slight injuries ranged from 7% [50] to 55% [54] (median 32% [38, 44, 50, 54] and 12.5% [35, 39]) of all injuries. Two studies [47, 48] reported minimal injuries taking 2–3 days to return to training and accounted for 26% [48] to 31% [47] of all injuries reported in the study. Minor/mild injuries defined as needing 4–7 days were reported in nine studies [35, 38, 39, 42, 44, 47, 48, 50, 54], ranging from 5% [54] to 31% [42] (median 26% [38, 44, 50, 54] and 26% [35, 39, 47, 48]). Three studies [34, 36, 53] used a scale of 3–7 days accounting for between 7% [36] and 41% [34]. Minimal/slight and minor were combined in one study [49], which resulted in 24% of all recorded injuries. Seven studies [34, 36, 38, 44, 50, 53, 54] classified moderate injuries as lasting up to 8–28 days and these injuries varied between 7% [54] and 67% [36] (median 37% [36, 38, 44, 50, 53, 54]). Moderate injuries were classified as requiring 7–28 days to return to training in five studies [35, 39, 42, 47, 49], with ranges of 30% [47] to 50% [49] (median 43% [39, 42, 47, 60]). Twelve studies reported severe injuries and defined them as lasting more than 28 days [35, 36, 38, 39, 42, 44, 47–50, 53, 54], and one study used > 29 days [34]. Severe injuries varied between 3% [54] and 32% [49] (median 18% [36, 38, 44, 50, 53] and 16.5% [35, 39, 47, 48]) of all injuries sustained in high-level youth football. Overall, 11 studies [34, 35, 37–39, 43, 45–48, 53] reported the average days lost to injury in youth football, which ranged from 12.5 days [37] for under 9- to under 16-year age groups to 28.7 days [34] for under 18- to under 21-year age groups. The pooled median number of days lost to injury were 15.3 [38, 41, 44–46, 53] and 21.9 [34, 35, 39, 47, 48].

Table 6 Distribution of injury types absolute and percentage (%) sustained by high-level male youth football players

References	Muscle strain/contracture	Ligament sprain/rupture	Tendon	Contusion/haematoma/tissue bruising	Fracture/dislocation	Laceration	Concussion	Overuse/growth	Joint injury	Other/unknown
Bacon and Mauger [40]	28 (33)	1 (1)		17 (20)	5 (6)			3 (4)		30 (36)
Bianco et al. [55]	93[a] (87)		14 (13)							
Bult et al. [44]	173 (28)	78 (13)	81 (13)	174 (28)	56[b] (9)					
Deehan et al. [33]	121 (41)	40 (14)	18 (6)	64 (22)				54 (18)		
Ergün et al. [54]	16 (55)	4 (14)	1 (4)	6 (21)			2 (7)			
Hawkins and Fuller [42]	60 (36)	33 (20)		44 (27)	7 (4)	5 (3)		2 (1)		15 (9)
Le Gall et al. [47]	176 (15)	192 (17)	108 (9)	352 (31)	78 (7)			19 (2)	97[c] (11)	130[d] (8)
Nilsson et al. [50]	46 (75)		3 (5)	4 (7)	1 (2)					7 (11)
Price et al. [39]	1141 (31)	767 (21)	162 (4)	569 (15)	166 (5)	31 (1)		192[e] (5)	230[f] (12)	439[g] (6)
Read et al. [35]	162 (22)	136 (18)	33 (4)	57 (8)	25 (3)	18 (2)		51 (7)	25[h] (32)	234 (3)
Renshaw and Goodwin [36]	58 (46)	20 16)	16 (13)							33 (26)
Tears et al. [38]	272[i] (31)	175 (20)	103 (12)	195 (22)	37 (4)	4 (1)	4 (1)		69 (3)	23 (8)

Percentages (%) are given in parentheses

[a]Includes cramps, strains

[b]Includes other bone injuries

[c]Includes 25 meniscal lesions, 72 osteochondroses

[d]Includes 78 vertebral lesions

[e]Includes 112 Osgood-Schlatter's disease, 57 Sever's disease, 23 other over-use

[f]Includes 79 periostitis, 71 inflammatory synovitis, 48 meniscal tears, 32 capsular tear

[g]Includes 117 lower back pain, 17 groin/abdominal hernias, 305 other diagnoses

[h]Includes 7 meniscus tears, 5 periostitis, 13 inflammatory synovitis

[i]Includes cramps, ruptures, strains

Table 7 Distribution of injury location absolute and percentage (%) sustained by high-level male youth football players

References	Ankle and foot	Lower leg (includes Achilles)	Knee	Posterior thigh	Anterior thigh	Upper leg	Groin/adductor/pelvis/hips	Upper body/sternum/ribs/upper and mid back	Finger/hand/arm/shoulder	Other	Head/neck/cervical spine
Bacon and Mauger [40]	32 (38)	2 (3)	14 (16)	3 (4)	6 (7)		14 (17)	6 (7)	2 (2)	3 (4)	3 (4)
Bianco et al. [53]		12 (11)	19 (18)			36 (34)	23 (21)			17[a] (16)	
Bult et al. [44]	162 (26)	55 (9)	103 (17)			106 (17)	142 (27)	6 (1)	33 (5)		13 (2)
Deehan et al. [33]	165 (27)		102 (17)	72 (12)	77 (13)		57 (9)	42 (7)		69[b] (11)	
Ergün et al. [54]	3 (10)	2 (7)	3 (10)	6 (21)	4 (14)		8 (28)			1[c] (3)	2 (7)
Le Gall et al. [47]	377 (31)	60 (5)	176 (14)			282 (23)	82 (7)	108 (9)	119 (10)	5[d] (0.41)	20 (14)
Hawkins and Fuller [43]	41 (27)	15 (10)	17 (11)			37 (18)	26 (17)	6 (4)		8[e] (5)	14 (9)
Merron et al. [34]	66 (28)	17 (7)	46 (19)	11 (5)	16 (7)		34 (14)	1 (0.4)	11 (5)	31[f] (13)	3 (1)
Nilsson et al. [50]	12 (20)	4 (7)	5 (8)			16 (26)	20 (33)		3 (5)	1[g] (2)	
Price et al. [39]	1062 (28)	375 (10)	644 (18)	414 (11)	313 (8)		476 (13)		72 (2)	362[h] (10)	37 (1)
Read et al. [35]	233 (30)	34 (4)	161 (21)	49 (6)	76 (10)		69 (9)		40 (5)	59[i] (8)	55 (7)
Renshaw and Goodwin [36]	22 (17)	7 (6)	22 (17)	17 (13)	27 (21)		17 (13)		8 (6)	6[j] (5)	1 (1)
Tears et al. [38]	206 (24)	101 (12)	122 (14)	77 (9)	102 (12)		133 (15)	15 (2)	44 (5)	59[k] (7)	16 (2)
Tourny et al. [49]	136 (25)	27 (5)	77 (14)			182 (33)	103 (19)		4 (1)	16[l] (3)	

Percentages (%) are given in parentheses

[a] Lower limb

[b] Five iliotibal band

[c] Pelvis, trunk, lower back

[d] Thorax, abdomen

[e] Torso

[f] Abdomen 14, spine 17

[g] Lower back, pelvis

[h] Lumbar spine 162, abdomen 26, sacro-iliac joint 26, others

[i] Lower back 40, abdomen, other

[j] Lower back 3, abdomen 3

[k] Lower back, pelvis

[l] Back 12, trunk 4

Table 8 Injury mechanisms absolute and percentage (%) in high-level male youth football

Injury mechanisms	References		
	Hawkins and Fuller [42]	Nilsson et al. [50]	Price et al. [39]
Running	15 (9)	17 (26)	736 (19)
Tackled/blocking	43 (26)	4 (7)	585 (15)
Other non-contact			291 (8)
Twisting/turning	14 (8)	1 (2)	274 (7)
Tackling	26 (16)		264 (7)
Kicked/knee		3 (5)	244 (7)
Collision	15 (9)	2 (3)	244 (7)
Passing		1 (2)	158 (4)
Shooting	21 (13)	6 (10)	145 (4)
Stretching		2 (3)	137 (4)
Landing	8 (5)	4 (7)	115 (3)
Falling		5 (8)	71 (2)
Hit by ball			45 (1)
Jumping	1 (1)		44 (1)
Diving			35 (1)
Other contact			33 (1)
Use of elbow			14 (0.4)
Dribbling			8 (0.2)
Heading	4 (2)		3 (0.1)
Not specified	11 (7)	10 (15)	362 (10)
Overuse	8 (5)	10 (15)	

Percentages (%) are given in parentheses

Table 9 Distribution of absolute and percentage (%) contact and non-contact injuries in high-level male youth football

References	Contact injury	Non-contact injury
Bacon and Mauger [40]	36 (45)	44 (55)
Deehan et al. [33]	210 (31)	475 (68)
Ergün et al. [54]	8 (47)	9 (53)
Nilsson et al. [50]	19 (31)	42 (69)
Price et al. [39]	1165 (34)	2281 (66)
Read et al. [35]	385 (38)	499 (62)
Renshaw and Goodwin [36]	36 (28)	91 (72)
Tears et al. [38]	315 (46)	377 (54)
Tourny et al. [49]	226 (36)	408 (64)

Percentages (%) are given in parentheses

3.7 Injury Type

Muscle strain injuries/contractures were reported by 12 studies [33, 35, 36, 38–40, 42, 44, 47, 50, 53, 54] and ranged from 15% [47] to 87% [53] (median 37% [36, 38, 44, 50, 53, 54] and 27% [33, 35, 39, 47]) of all recorded injuries

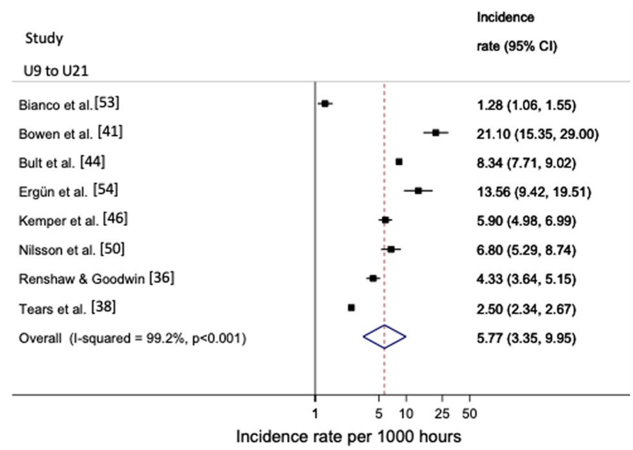

Fig. 2 Heterogeneity of match injury incidence rates between studies for players aged under 9 to under 21. Weights are from random effects analysis. *U* under, *CI* confidence intervals

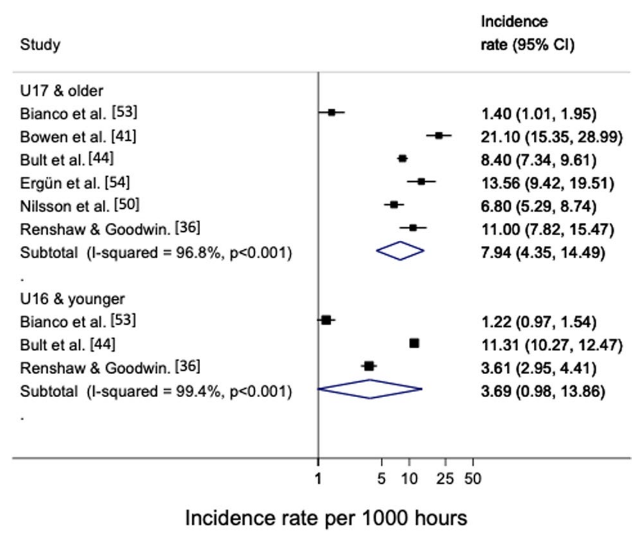

Fig. 3 Heterogeneity of match injury incidence rates between studies for players aged under 17 to under 21 and under 9 to under 16. Weights are from random effects analysis. *U* under, *CI* confidence intervals

(Table 6). Ligament injuries were found in ten studies [33, 35, 36, 38–40, 42, 44, 47, 54] and accounted for 1% [40] to 21% [39] (median 15% [36, 38, 44, 54] and 19% [33, 35, 39, 47]) of injuries sustained in high-level youth football. Tendon-related injuries ranged from 3% [54] to 13% [53] (median 12% [36, 38, 44, 54] and 5% [33, 35, 39, 47]) of all injuries and were reported in ten studies [33, 35, 36, 38, 39, 44, 47, 50, 53, 54]. Ten studies [33, 35, 38–40, 42, 44, 47, 50, 54] found contusions (including tissue bruising) to be responsible for 7% [50] to 31% [47] (median 21% [38, 44, 50, 54] and 18% [33, 35, 39, 47]) of all injuries that occurred in youth football. Overuse combined with growth-related injuries were reported in seven studies [33, 35, 39, 40, 42, 44, 47] and joint injuries in four studies [35, 38, 39, 47], accounting for between 1% [42] to 18% [33] and 3% [38] to 32% [35], respectively. The remaining injuries consisted of fractures (2–9%) [35, 38–40, 42, 47, 50], lacerations (< 1–3%) [35, 38, 39, 42], concussions (< 1–7%) [38, 54] and other/unknown 3% [35] to 36% [40].

3.8 Injury Location

Sixteen studies [33–36, 38–44, 47, 49, 50, 53, 54] (Table 7) reported injury location with data extraction not possible with three studies [51, 52, 55]. Injuries to lower limb were most common, ranging from 72% [35] to 93% [50], with all 16 studies in agreement [33–36, 38–45, 47, 49, 50, 54]. Pooled consensus study [36, 38, 41, 43–45, 50, 54] data recorded 85% and 48-h injury definition studies [33–35, 39, 47]; 79% of all injuries affected the lower limbs. Ankle in combination with foot injuries was reported in 13 studies [33–36, 38–40, 42, 44, 47, 49, 50, 54], varying between 10% [54] and 38% [40] (median 22% [36, 38, 44, 50, 54] and 29% [33–35, 39, 47]) of all injuries. Knee injuries made up 8% [50] to 21% [53] (median 15% [36, 38, 44, 50, 53, 54] and 17% [33–35, 39, 42, 47] of injuries that occurred in youth football and was reported in 14 studies [33–36, 38–40, 42, 44, 47, 49, 50, 53, 54]. Posterior and anterior thigh injuries were found in seven studies, accounting for 4% [40] to 21% [54] (median 5% [36, 38, 54] and 8% [33–35, 39]) and 7% [34] to 21% [36] (median 7% [36, 38, 54] and 7% [33–35, 39]), respectively, of all recorded injuries [33–36, 39, 40, 54]. Injuries only defined as upper leg were reported in six studies [38, 42, 44, 47, 50, 53], and were responsible for 18% [42] to 34% [53] (median 9% [44, 50, 53]) of injuries within high-level youth football. Groin injuries (including adductor/pelvis/hip area) were found in 14 studies [33–36, 38–40, 42, 44, 47, 49, 50, 53, 54], ranging from 7% [47] to 33% [50] (median 19% [36, 38, 44, 50, 53, 54] and 11% [33–35, 39, 47]) of sustained injuries. Other injuries consisted of finger/hand/arm/shoulder (< 1% [49] to 21% [34]; median 5% [36, 38, 44, 50] and 4% [34, 35, 47]) [34–36, 38–40, 44, 47, 49, 50], head and neck/cervical spine (< 1–14%; median 2% [36, 38, 44, 54] and 2% [34, 35, 39, 47]) and upper body, which included sternum/ribs/upper back/mid back (< 1% [34] to 9% [47]; median 1% [38, 44] and 2% [33, 34, 47]).

3.9 Injury Spikes

Six studies [33, 35, 39, 42, 47, 48] reported injury spikes that were time points during the course of a football season when injury occurrence was notably high. September (end of preparation period) was found to be the prominent month for sustaining an injury [33, 35, 47, 48], although one study observed an injury spike during the preparation period (August) [39]. Three studies [35, 39, 48] recorded injury spikes in season during winter (January) and one study towards the end of the season in March [33]. A single study [42] observed a gradual increase in injuries as the season progressed with a peak at the end of the season in May.

3.10 Mechanism of Injury

Three studies [39, 42, 50] reported the activity during which the injury occurred (Table 8). Running, which included very high speed, high speed and jogging, accounted for over a quarter of all injuries in one study [50] and only 9% in another [42]. Being tackled by an opponent was responsible for 7% [50] to 26% [42] of injuries to youth football players. Tackling an opponent or being kicked was responsible for 7–16% [39, 42] and 5–6% [39, 50] of the total injuries recorded, respectively. Situations involving non-contact with an opponent such as twisting/turning or landing ranged from 2 to 8% [42, 50] and 3 to 7% [39, 50]. Overall, nine studies [33, 35, 36, 38–40, 49, 50, 54] reported contact versus non-contact injuries, with eight studies [33, 35, 36, 39, 40, 49, 50, 54] finding non-contact more common than contact injuries. Non-contact injuries accounted for between 53% [54] and 72% [36] (median 66% [36, 38, 50, 54] and 66% [33, 35, 39]) of all injuries involving youth players in under 9- to under 21-year age groups (Table 9). Four studies [33, 39, 40, 42] reported that match play was responsible for the majority of injuries, ranging from 51% [33] to 66% [40] (median 51% [33, 39]). However, training was found to account for 34–72% (median 64% [36, 38, 50] and 71% [47, 48]) of injuries for under 9- to under 21-year age groups in nine different studies [33, 36, 38–40, 42, 47, 48, 50].

3.11 Playing Position

Six studies [33, 38–40, 47, 48] provided data on injury and playing position, but data could only be extracted from four studies [39, 40, 47, 49]. Only one study [40] provided positional incidence rates per 1000 h. Central midfielders displayed the highest risk of injury (14.22 ± 15.46 per 1000 h), and lateral midfielders had the lowest risk of injury (2.15 ± 2.49 per 1000 h). In the remaining four studies, goalkeepers sustained the fewest injuries, ranging from 8 to 14% [47, 49], followed by attacking players with 15–22% [39, 49]. Midfielders and defenders incurred the highest number of injuries, accounting for 37–41% [49] and 26–44% [47, 49], respectively [39, 47, 49].

4 Discussion

The aims of this systematic review were to provide an updated and comprehensive summary of high-level/elite youth football injuries and to calculate the risk of incurring an injury over one season. The main finding of this review was that the probability of high-level youth football players sustaining a time-loss injury during a season was 50% for studies [36, 38, 41, 43, 45, 46, 50, 53, 54] that used the injury consensus statement [56–58]. A further aim of our review was to provide pooled data of injury incidence per 1000 h for total exposure where injury definitions permitted [56–58]. For players aged under 17 to under 21 years pooled injury incidence per 1000 h was 7.9 (95% CI 4.4–14.5) [36, 38, 41, 50, 53, 54] and for players from under 9- to under 16-year groups, was 3.7 (95% CI 1.0–13.9) [38, 53]. The pooled overall injury incidence per 1000 h for age groups from under 9 to under 21 years was found to be 5.8 (95% CI 3.4–10.0) per 1000 h [36, 38, 41, 44, 46, 50, 53, 54]. Of all injuries reported, between 3% [54] and 32% [49] (median 18% [35, 36, 38, 39, 44, 50, 53] and 23% [35, 39, 47]) were severe, requiring an absence from training and playing for more than 28 days. In general, the most frequently occurring injuries resulted in soft tissue damage, with more serious injuries such as fractures featuring less. Lower limb injuries were the most common, with those to the ankle, knee and hip/groin region featuring the most. Running (including sprinting) and being tackled by an opponent were the most often reported injury mechanisms. Defenders and midfielders were the positions associated with higher injury rates.

4.1 Injury Incidence, Prevalence and Severity

To the best of our knowledge, this is the first review that reports on the probabilities of a high-level youth footballer sustaining an injury over one season (Table 4). Playing youth football over a season was associated with a greater than 50% risk of sustaining a time-loss injury [34, 36, 38, 41–43, 46, 49, 50, 52, 54]. Seven studies also reported a time-loss injury probability greater than 70% [36, 41, 42, 49, 50, 52, 54] and two cohorts reported greater than 90% [36, 54]. Calculating injury risk in the form of percentage probability has been used previously in rugby [29, 30] with a 6–98% risk of injury being reported [30]. Direct comparisons between high-level youth football and youth rugby are not advised. These sports are very different; however, our results do highlight that playing youth football at a high level poses a substantial risk of injury over the course of a typical season. While injury at senior levels can have negative effects on the team and its success rate [61, 62], the impact of injury on development within high-level football is yet to be established. It could be assumed that time away from training and matches would likely be associated with impaired tactical, technical and physical progress that would be anticipated if the injury had not been acquired. The effect of injury on a youth player's development is difficult to quantify, and recognising the risk of injury for a young person participating in youth football of a high level is essential for parents, players, coaches and other stakeholders. Communicating injury incidence as a percentage probability can assist in a comprehensive understanding of the risk associated with high-level youth sports [63]. The high probability of injury in high-level football occurred despite the introduction of the '11+' injury prevention programme in 2008 [64]. This warm-up programme focuses on reducing lower limb injuries by educating coaches and players on exercise execution and progression to performing the programme at least twice a week. A narrative review [65], concluded that the '11+' was effective in preventing non-contact injuries in youth amateur players. More recently, Rössler and co-workers [66, 67] using a cluster randomised, controlled trial over a single season, reported the '11 + Kids' for under 9- to under 13-year players reduced football injuries by 50% and healthcare costs by 51%; however, the effectiveness of the '11+' and '11 + Kids' remains to be investigated within high-level youth football. The burden of youth football injury to professional clubs' finances and national healthcare systems also remains unknown.

In the studies reviewed, training was associated with lower rates of injury when compared to matches, which is consistent with previous reviews [22, 23], a systematic review [24] and other field sports [68, 69]. Similarly, observations on senior professional players also have shown a reduced injury incidence when training compared to match play [16, 70, 71]. In general, the older aged (under 18 and under 21 years) [34, 36, 40–43, 50, 52, 54] had the highest rate of injury during training, which is comparable to the 4.3–5.8 per 1000 h reported for senior professional players competing in UEFA Champions League, Swedish and Middle Eastern football leagues [17, 61, 70, 71]. Ergün and co-workers [54] reported a training incidence rate of 0.0 per 1000 h; however, this was most likely due to the data being collected at national team training camps and limited exposure time (330 h) for that particular age group. Match injury rates for under 18- to under 21-year [53, 54] age groups were also similar to those reported in elite senior players (8.0 [14] to 65.9 [72] per 1000-h exposure). It should, however, be noted that the match injury incidence rates per 1000 h are higher than those reported in past reviews investigating injury in youth football [22, 23]. For younger ages (under 9 to under 16 years), injury rates exceeded both the minimum and maximal range for elite senior, under 18- to under 21-year groups [36] and also the 4.47 (95% CI 4.0–5.2) injuries per 1000 h reported in amateur boys' and girls' football [73]. Players in the younger cohorts would have less tactical knowledge and may have to rely on a greater physicality during matches, presenting different injury risks compared to older players [74]. Maturation may partly affect the findings of similar injury rates between older youth and senior footballers, since most of these cohorts would have cleared the rapid growth stage, which can cause disruption to motor control, heightening injury risk [45, 75]. Malina [76] found that footballers below 14 years of age were at the greatest risk of injury due to maturity status, but also the time spent training and playing in matches. A combination of sport specialisation before puberty [77] and full-time training resulting in faster and stronger players [78, 79] could explain the high injury probability and incidence rates for high-level youth players. Although growth is relevant for those at peak height velocity (PHV), its impact on injury seems smaller for the older cohorts (under 18 years and older) as these would have likely cleared the rapid changes in PHV. Monitoring growth-related variables to individualise exposure to systematic training and game play during periods of rapid physical growth and biological maturity could be beneficial for reducing injury rates in youth football players [80–82]. However, more research is required focusing on use of longitudinal measures of growth such as height change velocity or cross-sectional measures of maturation (bone age) and their relationship to injury rates in youth football.

Increased injury rates have previously been associated with advancing chronological age in youth football [39, 47, 51, 52, 60]. Information in this review suggests that injury incidence, whether in training or matches, does not always increase with chronological age, as reported in a recent systematic review [83]. Three studies in our review reported younger age groups having a higher injury incidence per 1000 h than their older peers at the same club [36, 49] or national team [54]. It is possible that younger players 'playing up' (i.e. competing against older players with advanced maturity) may have affected the injury rates reported in these studies [36]. When selecting a youth player to 'play up', medical and technical staff may consider discussing the player's growth phase and ability to cope against stronger more mature players, and, if required, implement an individualised periodized training/match plan to off-set injury risk [82, 84]. While growth may be associated with some injuries, it may be that increased physicality and competitiveness are likely to have greater impact [39]. The strength of evidence for injury incidence in high-level youth football, however, is limited by the heterogeneity of research design, sample sizes and injury definitions. Caution should also be exercised when interpreting injury incidences from the literature, as each club's training and match selection process would be unique [36] and dependent upon the club principles of play.

Over two-thirds of the studies analysed in this review found that severe injuries (return to training beyond 28 days) accounted for more than one-fourth of all injuries (range 3–32%; median 18% [36, 38, 44, 50, 53] and 16.5% [35, 39, 47]) sustained in youth football, in comparison to 16% reported by Ekstrand et al. [14] for senior players. In youth football severe injuries have been previously reported to make up 23.7% [73] and 10–15% [23]. One severe injury per season to a high-level football player represents a minimum of 10% of their development time lost. The potential for significant time loss through injury in youth football appears to be high, which could affect training, competing, and education and family finances. More research is required to provide a holistic understanding of the impact of injury on high-level youth players. Our review included 7953 players with 2346 reported muscle-strain injuries, translating to 27% (median; 48-h injury definition) to 37% (median; consensus statement) of all injuries sustained by youth football players, similar to the 31% reported in senior professional players [16]. While the precise locations of these muscle injuries are difficult to identify due to varying definitions and research designs, the regions most affected suggest musculature of the lower leg, hip/groin, and posterior and anterior thigh, which is comparable with professional players [16]. During adolescence, the hip/groin/pelvis region undergoes morphological changes that may predispose high-level youth players to increased injury risk [85]. In the adult literature, hip/groin and hamstring strain injuries have received substantial attention [86–89]. Studies have shown that it is possible to reduce hamstring [90] and groin [91, 92] injuries; therefore, attention should be paid to evidence-based strengthening exercises for these susceptible regions. Currently, however, little information is available on normative levels of strength required to avoid injury or other causative factors of hamstring, hip and groin injuries in youth football. This is despite the fact that hip, groin, hamstring strain and overuse injury have been linked to chronic maladaptations [7, 10, 93] that may go on to influence pathology at senior level [94], potentially impacting upon player availability and club finances [95].

4.2 Injury Occurrences

The preparation (pre-season) periods used in youth football may be too short to adequately prepare players to withstand the loads placed upon them during the season [96], especially since academic assessments may overlap with the preparation period in youth football. It is also possible that fatigue can accumulate over the preparation period, as coaches look to push players tactically, technically and physically without providing sufficient recovery and rest [35, 39]. Differences in physiological recovery ability between established senior players and younger emerging players transitioning into the senior squad have been reported [97]. It is possible that new recruits into high-level youth teams from lower levels of play may inefficiently recover compared to their more established peers. Little information is available relating to youth football players or athletes undergoing rapid growth and their ability to recover fully from training or competition. More attention may be paid to the implementation of a gradual build-up of training activities during the preparation period alongside appropriate monitoring of training loads and off-season conditioning. January [35, 39, 48] was also identified as a period of elevated injury occurrence, which coincides with the Christmas holidays. Accumulation of fatigue during the first part of the season and a shorter break over the Christmas period may explain the injury spike in January. In senior football reducing a winter break from 6.5 to 3.5 weeks was found to increase knee and training injury incidence rates [98]. It was suggested that too little recovery time promoted lower levels of neuromuscular control, altering biomechanics and increasing injury [99–101]. Regional differences in climate could also be important to consider for youth football and injury. In the northern hemisphere, it is likely that the shift in climate around this time may have an impact on player safety. Colder, wetter weather might cause variations to playing surfaces, leading to tougher playing and training conditions, adding to injury risk [102]. Ekstrand et al. [96] found that teams training and playing in northern Europe had a higher overall injury incidence than teams located in southern Europe. However, it is also possible that periods of total inactivity or insufficient stimulus may lead to de-training and then when footballers are exposed to large jumps (spikes) in training loads pre-winter break they do not cope well and break down. It may therefore be important that coaches and support staff understand the principles of volume and intensity within a football context. More research is needed on the effects and timescale of de-training and off-season conditioning of youth players.

4.3 Injury Mechanisms and Consequences

When all of the studies were analysed according to injury definition (48 h [33, 35, 39], consensus statement [36, 38, 50, 54]), non-contact injuries accounted for 66% of all injuries independent of definition. Two studies observed that running (including sprinting) was the most injurious activity within high-level youth football [39, 50]. Given that non-contact injuries may be regarded as preventable, training strategies to address these issues should be considered for youth players. These preventive strategies should focus on the ankle, knee and hip of high-level youth football players. Evidence to support such approaches to physical preparation is available in recent meta-analyses [103, 104], suggesting that 10–15 min two to three times weekly of neuromuscular training activities would be sufficient to reduce non-contact injuries by 45%. Faude et al. [103] also reported larger effect sizes ($g = 0.34–1.18$) in studies that used high-level players, although these results should be carefully interpreted especially since CI overlapped. More research into appropriate exercise selection and timing (before or after training) for injury prevention with a specific focus on high-level youth athletes is required. Time lost to injuries in studies included this review varied between 5% [37] and 11% [34] of the youth season, similar to that reported for elite senior football [14]. Ekstrand et al. [14] found that a senior player would suffer on average 2.0 injuries per season. Translating this finding to youth football may cause an absence from training and playing due to injury of 10% [37] and 22% [34] for under 9- to under 16-year and under 18- to under 21-year age groups, respectively. Such time loss to injury could be devastating for high-level youth players, since regular engagement in training exercises that are designed to improve performance have been proposed as contributing to achieving elite status [2].

However, the professionalisation of youth football has meant that many youngsters in professional high-level youth systems become single-sport specialists. Early specialisation has raised concerns in the sports medicine and exercise science literature, questioning the benefits of these developmental programmes [105–109]. Recently a systematic review found that athletes who had a high-level of single-sport specialisation were at an increased risk of sustaining musculoskeletal overuse injuries compared with athletes with low (pooled relative risk [RR] ratio: 1.81; 95% CI 1.26–2.60) and moderate (pooled RR ratio: 1.39; 95% CI 1.04–1.87) specialisation [110]. An article excluded from that systematic review due to age range also reported a higher number of serious injuries (0.54 ± 0.83) when compared to athletes who did not (0.23 ± 0.42) focus on a single sport [111]. High training volume [112] associated with early specialisation may promote limited athletic exposure and sampling of other sports, decreasing motor and athletic development, and increasing injury risk as players transition development cycles [113]. Injury occurrence early in youth players' careers would heighten the risk of future injury with previous injury being an established injury risk factor [114, 115]. Early occurrence of injury to a young footballer could result in low availability for training and matches, limiting time that the technical staff have to develop players' tactical, technical and physical competence and reducing the chances of players securing further contracts. The negative long-term health consequences of sustaining an injury early in a youth player's career include degenerative changes [11], suboptimal and/or loss of neuromuscular function [10] or career termination [116]. A youth player injured for the first time may not understand how to handle loss of identity [117] and parent, coach and peer-performance expectations [118] or setbacks within the rehabilitation process. Injuries could also negatively affect the psychology of the injured player and possibly the whole squad if the injury was sufficiently traumatic. Reducing physical activity due to injury may encourage 'over-protection' from parents, club staff and players. Such 'over-protection' could limit youth players' physical 'robustness', leaving the player vulnerable to injury in subsequent development cycles [119]. Further research is required to investigate the longitudinal impact of injury on the development of high-level youth football players from a multi-disciplinary perspective.

5 Methodological Considerations

5.1 Strengths

To date this is the first comprehensive systematic review of its kind to examine all published data for injury probability, incidence, prevalence and severity in high-level youth football that combines the results of analytical studies to strengthen the results. Given the large number of studies consisting of several teams and the fact that they examined players across a number of diverse regions, the findings within this systematic review could be generalised to youth football players competing at a high level of play across Europe.

5.2 Limitations

The heterogeneity of injury definitions may explain the large ranges found in injury incidence rate in matches and training, location, type and severity. Large variations in injury location may be the result of some studies combining injury categories into regions such as groin, hip and pelvis and others differentiating hip joint injuries from groin injuries. This may under- or overestimate injuries in these regions, making reliable comparisons between studies difficult. Reporting injuries using a medical attention definition [51] may have resulted in a much larger injury rate per 1000 h than a definition of injuries severe enough to prevent a player from training or competing in football for 7 days [55]. Studies using a medical attention definition have the potential to record injuries with less reliability, clinical importance and interest, and they may also record a higher number for injuries [120, 121]. Only seven studies [33, 35, 39, 40, 42, 44, 47] in this review reported injuries that could be classified as overuse or growth related, but no definitions were provided. Since players can often train and play on with such an injury [122], this may have resulted in under-reporting of injuries in some of the articles evaluated in the present review. The definition, recording and reporting of overuse injuries in high-level youth football warrants further investigation [123, 124]. Further evidence in the literature of under-reporting of time-loss injuries also exists. Bjorneboe et al. [125] found that Norwegian medical staff working in professional football failed to report around 20% of time-loss injuries. More recently, clinicians collecting injury data for research purposes have also been observed to significantly affect reported rates of injury [126]. The individual or team making the injury diagnosis may be another factor that contributes to variation in injury incidence reporting. In addition, differences in levels in expertise have been shown to account for variations of diagnosis outcomes [127]. For the studies included in our review, a wide range of personnel were involved in the reporting process, including physiotherapists, sports physicians and coaches, and it is possible that these different personnel also introduce a source of bias [36]. To make future injury data comparable in youth football, the consensus statements by Fuller et al. [56–58] should be adopted and followed. Due to a lack of suitable data, our review was unable to convert pooled match incidences into probabilities of injury over one season. We recommend that future studies should consider reporting the number of injuries sustained in training and match separately, and the severity, injury type and location as per 1000-h exposure to ensure standardisation. Injury burden (the product of severity and incidence [128]) should also be reported in future youth football injury surveillance studies to conform to healthcare research and allow comparisons with other sports for the same injury [128]. It is clear that many factors, both internal and external, contribute to injury of high-level youth football players, such as pitch, maturation status, anthropometric characteristics, strength, speed, previous injury, age of specialisation, match selection, training process, playing and coaching style. Future research is needed to address injury prevention for lower-limb injuries, specifically ankle, thigh, groin and hip, in youth football players. A perceived weakness of this study may be that it was limited to English-language publications only, resulting in a total of 30 papers being excluded. To address this concern, post hoc, these studies were reviewed to explore bias as a result of the restriction. Of those 30 papers excluded, only one paper [129] contained any data of interest; however, the retrospective study design meant it failed to meet the inclusion criteria. A lack of evidence of language bias has previously been reported in other fields of study [130], potentially strengthening the findings of our review.

5.3 Future Perspectives

The information gathered in our review demonstrates the need for well-designed injury prevention programmes to limit the negative effects associated with injury in high-level youth football. To meet the epidemiological challenges presented by youth football, routine injury surveillance needs to be improved so it can be used to assist the developmental needs of youth players.

6 Conclusion

We found high probabilities of sustaining a time-loss injury over one typical high-level youth football season. Many similarities exist between youth and senior football injury patterns such as training and match incidence, prevalence and severity rates. Youth players lose large portions of their seasonal development potential to injury, with players seemingly suffering long absences from training and matches, consequently affecting health and well-being and possibly burdening club/parent finances and healthcare systems.

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Data Availability The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

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