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Match and Training Injuries in Women's Football: A Systematic Review and Pooled Analysis of Published Studies

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Abstract

Background: The injury risk to female football participants is high with 48% to 70% of all players sustaining at least one injury during a season. The majority (69% to 85%) of these injuries are acute onset.

Objective: To review and calculate pooled data estimates for women's football injury epidemiology for participation levels in match and training environments.

Methods: A systematic review and pooled analysis for published studies reporting women's football match and training injuries including estimated costs. Searches were performed in PubMed, CINHAL, Science Direct, Scopus, SPORT Discus, Springer Link and Wiley Online databases. Studies were considered if they reported women's football match or training injuries between Jan 1990 to Dec 2021. Two authors extracted study characteristics, numerical data and assessed article quality by adhering to the protocols for systematic review of observational studies (MOOSE) and **Strengthening and Reporting of Observational studies in Epidemiology (STROBE)** statements.

Results: Of 36 articles identified as eligible for the systematic review, there were 363,652 match-hrs with 8,608 injuries and 2,924,138 match-athlete exposures (AE) with 15,470 match injuries resulting in pooled match injury incidence rates (IIR) of 23.7 (95% CI: 23.2 to 24.2) per 1,000 match-hrs and 5.3 (95% CI: 5.2 to 5.4) per 1,000 match-AEs. Of the total estimated female football injury costs (NZD$257,667,307) 63.6% were attributed to match injuries. There were more pooled injuries recorded for the lower limb (20.5 (95% CI: 19.8 to 21.3) per 1,000 match-hrs) than to the chest-back-other (RR: 7.4 (95% CI: 6.6 to 8.2); $p<0.0001$; $d=1.03$), upper limb (RR: 7.0 (95% CI: 6.3 to 7.7); $p<0.0001$; $d=1.04$) and head-neck (RR: 4.0 (3.7 to 4.3); $p<0.0001$; $d=0.91$) body regions. There were significantly more pooled contusions (19.8 (18.6 to 21.0) per 1,000 match-hrs) than sprains (RR: 1.8 (95% CI: 1.3 to 1.5); $p<0.0001$; $d=0.65$), strains (RR: 3.4 (95% CI: 3.0 to 3.9); $p<0.0001$; $d=1.07$) and concussions (RR: 19.8 (95% CI: 16.4 to 23.9); $p<0.0001$; $d=1.31$). Studies on female junior participants reported more training injuries (10.1 (9.5 to 10.7) per 1,000 training-hrs) than studies reporting on female adolescent (RR: 6.6 (95% CI: 5.5 to 7.8); $p<0.001$; $d=0.76$), amateur (RR: 3.8 (95% CI: 3.5 to 4.1); $p<0.0001$; $d=0.34$) and elite (RR: 2.8 (95% CI: 2.6-3.1); $p<0.0001$; $d=0.48$) level participants.

Conclusion: Injury prevention interventions need to focus on female junior football players to reduce lower limb injuries and contusions.

Key Points:

- Based on 35 studies, estimates of pooled injury incidence for female football match-related activities ranged from 20.9 per 1,000 match-hrs (junior) to 29.2 per 1,000 match-hrs (elite).
- Based on 25 studies, estimates of pooled injury incidence for female football training-related activities ranged from 1.6 per 1,000 training-hrs (adolescent) to 10.1 per 1,000 match-hrs (junior).
- The estimated match injury related costs were NZD$58,897,320 for studies reporting per 1,000 match-hrs and NZD$104,997,334 for studies reporting per 1,000 AEs.

ABBREVIATIONS

AE: Athlete Exposures; CI: Confidence Interval; hrs: hours; IIR: Injury Incidence Range; MOOSE: Meta-analysis Of Observational Studies in Epidemiology; mTBI: mild Traumatic Brain Injury; NOS: Newcastle-Ottawa Scale; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO: Prospective Register of Systematic Reviews; RR: Risk Ratio; SPSS: Statistical Package for Social Sciences; STROBE: Strengthening and Reporting of Observational studies in Epidemiology.

INTRODUCTION

Female participation in football (also known as soccer) [1, 2], has experienced an exponential growth in recent years, with an estimated 13 million amateur and elite participants worldwide [3], As a result of the high intensity movement patterns [4,5], combined with frequent collisions, football is in the top five sports where participants are most at risk of sustaining an injury [6,7]. Although males are at a higher risk of injury during football compared with females [8-10], females are more likely to suffer severe injuries compared with males [10]. Skill levels of females compared with male participants and decreased medical support for female teams have been suggested as potential confounding risk factors [10]. Of all female participants, 48% to 70% sustain at least one injury during a football season [11,12], and 69% to 85% of these injuries are acute in onset [11-13]. To address the large financial losses of professional participants and increasing player withdrawals of amateur participants due to injuries [14], the Fédération Internationale de Football Association (FIFA) developed an injury prevention programme in 2006 called FIFA 11+. The programme has been widely adopted owing to its effectiveness and easy application with between 30% [15], to 46% [16], reduction in lower extremity injuries having been reported for males and 32% for females [17].

As other recent systematic reviews have been limited to either junior [18], adult [3], or elite [7], female studies, the object of the current study was to conduct a systematic review and pooled analysis of the incidence of injuries (location, type, site, severity, match and training) and their estimated costs for female football players at all levels of participation.

METHODS

This systematic review was carried out following the suggested methodological framework for scoping reviews [19,20], the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21], and the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) [22], guidelines. The methodological framework for scoping reviews involved five major steps (1: identify research question; 2: identify relevant studies; 3: select studies; 4: chart data; 5: collate, summarize, and report results). The preliminary search for data was guided by the research question: "*What are the estimates and costs of injuries in female football when pooled and at different levels of participation*".

PRISMA and MOOSE guidelines contain checklists that were utilised for conducting and reviewing the included studies. Methodology utilised in this pooled analysis was similar to previous pooled analysis studies [23,24], and followed steps described by Friedenreich [25,26]. An advantage to utilising a pooled analysis approach is that the same statistical model can be utilised with data from methodologically diverse studies [27]. The review was registered on 24th November 2021 with the International Prospective Register of Systematic Reviews (PROSPERO; http://www.crd.york.ac.uk/PROSPERO/), registration number: CRD42021287136.

Eligibility criteria were established based on the concept of population, intervention/indicator, comparator/control, outcome and study design (PICOS) [28,29], (Supplementary Table 1). Thus, to be included in this systematic review and pooled analysis, studies had to fulfil the following criteria:

1) Participants had to be female football players.
2) Studies had to be prospective in design and the full text of the article reporting results of the study had to be published in English in a peer-reviewed journal before 31st December 2021.
3) Studies needed to report the injury incidence rate (IIR) or the injury prevalence amongst the enrolled participants or provide data sufficient from which IIR could be calculated.
4) Studies had to report on football competition/match or training injuries.

Studies excluded were those that reported solely on collision injuries, did not report match exposure hrs, did not report injury data, only reported overall (match and training) injuries but did not report these separately, reported only head impact biomechanics, reported data already included in the review, utilised a survey questionnaire, were reviews, or reported self-reported injuries.

Studies reviewed but excluded, were retrospective [10,30,31], not peer reviewed [32,33], systematic reviews [2,3,7,18,34-42], did not provide enough information to establish the injury incidence or exposure hours [8,43-52], utilised a self-reporting questionnaire or survey [44,53-59], reviewed emergency department records [60,61], combined match and training data [12,30,56,62,63], reported on a specific injury [41,46,64-74], or reported previously included data [69,75].

A systematic computerised search was conducted for articles published between 1st January 1980 and 31st December 2021 in databases: Web of Science, SPORTDiscus, SCOPUS, PubMed, and EBSCO CINHAL Complete. A search of reference lists of included articles and a Google Scholar search were also performed. This was conducted utilising forward (scanning a list of articles that had cited a given paper since it was published) and backward (manually searching the reference list of a journal article) citation tracking [76]. When additional studies were identified that met inclusion criteria they were included in the systematic review and pooled analysis. Relevant search terms were used to construct Boolean search strategies (Supplementary Table 2).

All references downloaded into a dedicated EndNote library (Endnote 20) were reviewed, and duplicate records identified and removed. All publications identified were initially screened by publication title and abstract to identify eligibility. Full-text versions of remaining articles were then retrieved and evaluated against the inclusion criteria. A study was excluded immediately when it failed to meet any of the inclusion criteria. In cases of discrepancies of eligibility another author assessed the publication to screen for eligibility.

All studies included in the pooled analysis were observational in design. Two authors extracted the study characteristics, numerical data and assessed quality, by adhering to the protocol for systematic review of observational studies (MOOSE) [22]. This approach enabled a more precise estimate of effects of influential factors and took into account confounding factors (participation level and age) and heterogeneity of studies [27].

Variables from included studies were coded and grouped into three categories (Supplementary Table 3): (1) General study descriptors; (2) Study population; and (3) epidemiological injury main characteristics (e.g., location, type, site, severity, onset and mechanism) and exposure data.

The purpose of the systematic review and pooled analysis was to determine the overall IIR on female football players for:

1) Match *vs*. training;
2) Injury location (head and neck *vs.* upper limb *vs.* lower limb *vs.* chest-back-other);
3) Injury type (contusions *vs.* sprains *vs.* strains *vs.* concussions);
4) Injury severity (minor: no loss of match or training time; *vs.* missed match: loss of match and/or training time);
5) Participation level (international *vs.* amateur *vs.* adolescent *vs.* junior);
6) Probability of an injury occurring over a season.

Studies meeting inclusion criteria underwent data extraction for information pertaining to level of participation, injury definition utilised [77], injury onset [78,79], injury type and site [78], match or training [78], injury severity [78,80], and player position/group [78], (Supplementary Table 3). Not all studies reported the same information in relationship to injury incidence.

All included studies were independently assessed by two authors reporting on the article quality utilizing the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement [81]. The statement provides a 22-item checklist guidance on the reporting of observational studies in order to facilitate a critical appraisal of the study and for results interpretation (Supplementary Table 4). Following the appraisal, included studies were categorised as poor, moderate or good quality based on the percentage of fulfilled items on the STROBE checklist, with cut-off values of <50, 50-80 and >80% respectively [82]. To assess for inter-rater reliability between the two reviewers, Cohen's Kappa (κ) coefficients were applied. Level of agreement was categorized as none, minimal, weak, moderate, strong and almost perfect with cut-offs of <0.20, 0.21-0.39, 0.40-0.59, 0.60-0.79, 0.80-0.90, and >0.90 respectively [83].

Two authors using an adapted version of the Newcastle-Ottawa Scale (NOS) for cohort studies (Supplementary Table 5) undertook risk of bias of external validity quality. The original NOS is a quality assessment tool for cohort and case-control studies which contains eight items categorised into three domains (selection, comparability, and exposure) and uses a star rating system to indicate the quality of a study (maximum of nine stars). The NOS has been modified previously in systematic reviews investigating epidemiology of injuries in other cohorts of sports participants [3,18,40]. For the current study, the modifications were similar to two previous studies [3,18,40]. In particular, two of the eight items were deleted. Item 2 was excluded because a selection of the non-exposed cohort was irrelevant as long as the total study population was exposed to football play and item 5 (comparability of cohorts based on the design or analysis) was excluded because it was linked to item 2. Three new items were added to the original scale (items 1, 3 and 4). Therefore, the criteria adopted to assess risk of bias were:

(1) Description or type of football players.

(2) Definition of football related injury.

(3) Definition of a sports-related concussion injury.

(4) Representativeness of the exposed cohort.

(5) Ascertainment of exposure.

(6) Demonstration that the outcome of interest was not present at the start of study.

(7) Assessment of outcome.

(8) Whether follow-up was long enough for outcomes to occur.

(9) Adequacy of follow-up of cohorts.

An article could be awarded a maximum of one star for each item if appropriate methods had been clearly reported. Thus, a total of nine stars could be given to an article. The higher the number of stars given to an article the lower the risk of bias. In addition to the NOS, the National Health and Medical Research Council (NHMRC) [84] Evidence Hierarchy was utilised to evaluate the level of evidence of all the included studies.

To enable meaningful comparisons, sports injury definitions of included studies were categorised into broad groups [85]. The definition of an injury is a contentious issue [86,87], and there have been many variations to what constitutes a recordable injury. Although there are two broadly accepted definitions (medical treatment and loss-of-time-fully-inclusive) there are advantages and disadvantages to these definitions [85]. Definitions utilised are dependent upon what the authors are reporting such as injuries that only result in missed match participation only (semi-inclusive time-loss), missed match and training (full-inclusive) or an all-inclusive injury definition [85]. Results of these different definitions are that some papers have reported some injuries (time-loss in match and training activities), or have eliminated them if they did not result in time-loss from matches [77,85] (Supplementary Table 6). All included studies were reviewed to identify any concussion definitions utilised.

A pooled analysis of included studies was undertaken where homogeneity occurred in terms of injury definition utilised and the reporting of injury incidence was per 1,000 match or training-hrs. This strategy has been previously utilised in rugby-15s [88-90] and rugby league [23,24,91] epidemiological studies to combine information provided into a single estimate [25,92]. By pooling data, the information provided can then be statistically re-analysed providing more precise injury data [25].

The mean costs per football injury in New Zealand have been previously reported for female participants [93]. This study was utilised to calculate the approximate associated costs for match and training injuries across all the studies included in this review. The reported mean costs for match and training injuries from this study were adjusted for inflation (Reserve Bank inflation adjustor; https://www.rbnz.govt.nz/monetary-policy/inflation-calculator) to 2022 values, calculated per reported injury and reported in New Zealand Dollars (NZD$).

The injury incidence rates (IIR) were extracted from included studies in either per 1,000 hrs of match or training exposure or per 1,000 athlete exposures (AE). If IIR were not specifically

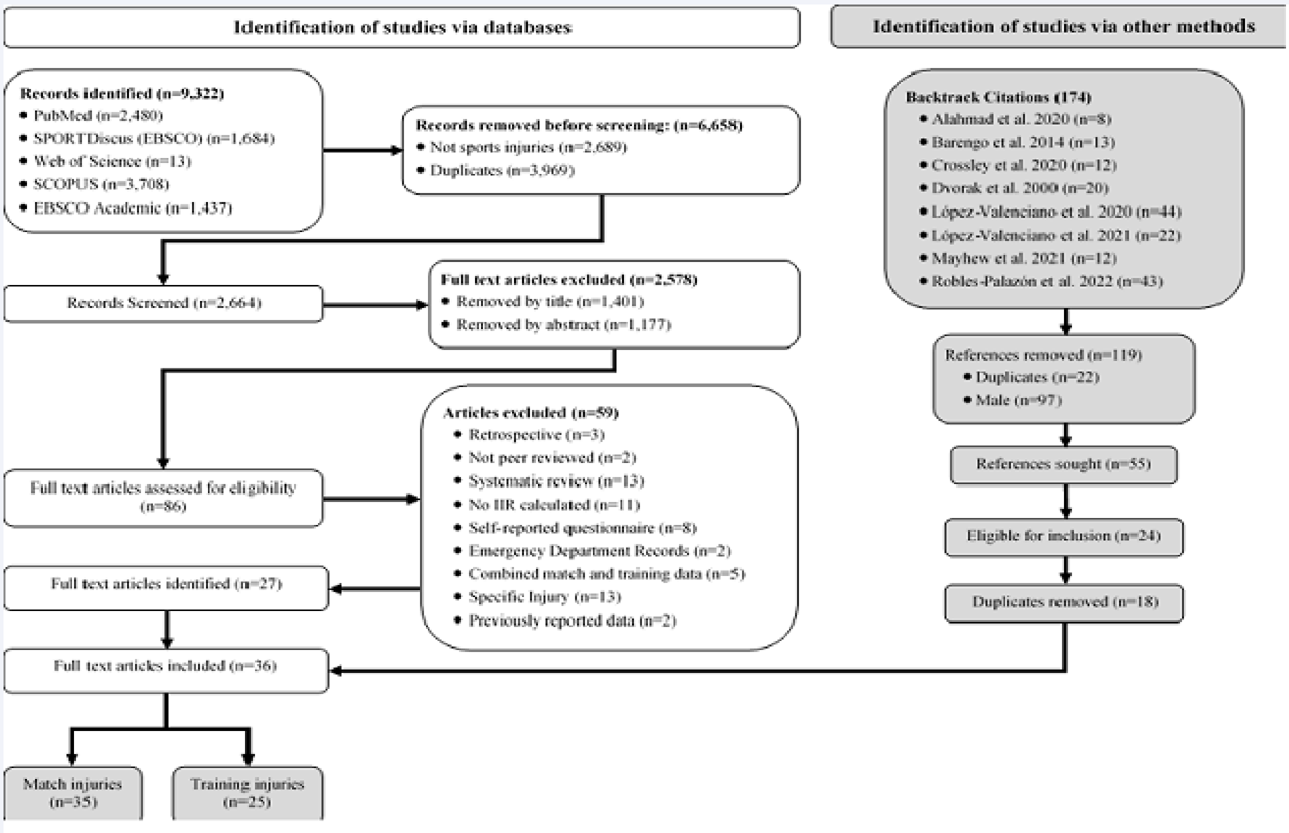

Figure 1 PRISMA 2020 [21] flow diagram for the identification, screening, eligibility, and inclusion for the literature reporting on female football match and training injuries.

reported, the rate, where possible, was calculated from available raw data using the formula [94]:

$$IIR = \left(\sum injuries \,/\, \sum exposure\right) x\ 1{,}000$$

where IIR were available, or where able to be calculated per 1,000 hrs, post hoc probabilities of a match injury occurring over a competition season were determined using a Poisson distribution [95]:

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

where κ is total number of injuries occurring in a squad of players and total time of match play exposure over a single season, t is time-interval in hours, e is base of the natural logarithm (e=2.71828…), $\kappa!$ is factorial of 'κ' and λt is injury incidence multiplied by length of exposure.

Previously utilised in studies reporting on rugby union [88,95] and football [18,96], the Poisson distribution for injury probability helps describe frequency of injuries occurring based on the presumption that these occur independently and take place over time or space [97]. To calculate injury probability incidence rate, the duration, and number, of matches played in a single season are required. Therefore, to utilise the Poisson distribution for injury probability, it must be presumed that each player within the squad would have a similar risk of sustaining an injury [95]. As such, probability calculations were undertaken based on match duration between 40 and 90 mins and injuries being independent events. If the number of matches were not reported or able to be calculated, then this was calculated as 30 per season for football [96].

A combined estimate of injuries within a specific sport through pooled analysis [98], provides more precise evidence and meaningful information about the sport, whilst controlling for between-study variation due to individual sub-cohort characteristics [25]. Data from individual studies were combined. Incidence rates and 95% confidence intervals (CI) were calculated [99], where data were available and reported according to the methodology utilised in the individual studies. The pooled calculation of injury incidence was undertaken to report incidence per 1,000 hr and 95% confidence intervals (CI). To compare between injury rates, risk ratios (RRs) and Cohen's *d* effect sizes were also computed to complement interpretation of results, with effect sizes being interpreted as negligible/very small (d<0.20), small (d=0.20 to 0.49), medium (d=0.50 to 0.79), or large (d>0.80) [100,101]. To test for significant differences between studies and player positions, chi-squared (χ^2) goodness-of-fit tests were utilised. Statistical significance was set at p<0.05. All statistics were carried out using the SPSS (IBM SPSS Statistics for Windows, Version 27.0, Armonk, NY: IBM Corp) statistical software packages.

RESULTS

The 36 [9, 11-13, 17, 75, 102-131], papers that met inclusion criteria included elite to junior levels of participation (Table 1). Nearly half (47.2%) of studies [9, 11-13, 17, 102, 106, 108, 111, 112, 117, 118, 121, 126-128, 130], were from Europe based teams, a quarter (25.0%) from the United States of America [104, 105, 107, 109, 110, 116, 120, 123, 124], and the rest (27.8%) from England [113, 125, 129, 131], Olympics / World cup competitions [75, 114, 115], or other [103, 119, 122], nations. There were no studies reporting on female football from the southern hemisphere.

There were 35 [9, 11-13, 17, 75, 102-109, 111-131], studies included in the study that reported match injuries. Thirty studies [9, 11-13, 17, 75, 102, 103, 106-109, 111-115, 117-122, 125-131], recorded 363,652 match-hrs and 8,608 injuries (Table 2). Five [104, 105, 116, 123, 124], included studies reported 2,924,138 match-AEs with 15,470 match injuries. There were 25 [9, 11-13, 17, 104-106, 108, 110-113, 116-118, 121, 124-131], studies that reported training injuries. The majority (21) of studies [9, 11-13, 17, 106, 108, 110-113, 117, 118, 121, 125-131], reported a total training exposure of 1,011,002 training-hrs and 3,689 injuries. Four [104, 105, 116, 124], studies reported 2,643,995 training-AE with 10,125 match injuries.

The STROBE quality scale mean score was 22.9 ±4.1 (minimum: 15, maximum: 32) (Supplementary Table 7). The STROBE quality scale inter-rater reliability was assessed as almost perfect (κ=0.908; p<0.0001) between the reviewers. The NOS mean score was 5.6 ±0.9 (minimum: 4, maximum: 8) (Supplementary Table 8). The NOS inter-rater reliability was assessed as strong (κ=0.815; p<0.0001) between the reviewers. All studies included in this systematic review were cohort studies and this represented Level III evidence.

Most (72.2%) studies [9, 11-13, 17, 102, 104-106, 109-113, 115-118, 121, 123, 125, 126, 128-131], utilised a full-inclusive time-loss injury definition. Nearly a fifth (16.7%) of studies [75, 114, 119, 122, 124, 127], utilised a medical attention/treatment injury definition, and 8.3% of studies [103, 108, 120], utilised all-inclusive injury definition. One study [107], did not provide an injury definition and no study utilised a semi-inclusive time-loss injury definition. No studies in the review reported a concussion definition although six studies [75, 106, 107, 114, 115, 120], reported on concussions.

Injury probability of a single injury occurring throughout the season varied from 36.5% probability at the collegiate level of participation [129], to 100% probability for a majority (n=19; 52.8%) of studies [9, 11, 12, 17, 102, 106, 107, 109, 111, 113-115, 118-120, 125-127, 132].

More than half (63.6%) of the total estimated female football injury costs (NZD$257,667,307) were attributed to match injuries (Table 2). Total estimated costs for match injuries reported by included studies were NZD$163,973,891. More than half (64.1%) of the estimated match injury related costs (NZD$105,076,572) were attributed to studies reporting AEs. Of these studies, female adolescents (34.6%) recorded the highest estimated costs (NZD$56,795,959). For those studies reporting match injuries per 1,000 match-hrs, Female juniors recorded nearly a fifth (12.3%) of the estimated match total costs (NZD$20,170,501) while female amateurs were slightly less (9.9%) costing NZD$16,297,819.

Table 1: Prospective epidemiological studies reporting on female football match and training injuries by participation level and country of origin.

Participation Level	Match	Training
Female Elite	Olympics[75, 115] World Cup[114, 115] Germany[11, 111] Sweden[9, 12, 13, 106] Europe[112] Spain[117] France[118]	Spain[117] Sweden[12, 106] Europe[112] France[118] Germany[11]
Female International	• England[125, 131]	• England[131]
Female Amateur	Trinidad & Tobago[103] United States of America[104, 105, 109, 120, 124] Norway[17, 130] Sweden[121] Germany[111] England[125] Nigeria[122] Ireland[113]	Sweden[9, 13, 121] United States of America[110] England[125] Norway[17, 130] Ireland[113] Germany[111]
Female Adolescent	Ireland[129] World Cup[115] Norway[127, 128] Kenya[119] United States of America[116, 123]	Ireland[129] United States of America[104, 105, 124] Norway[128]
Female Junior	Denmark[102] World Cup[115] United States of America[107] Norway[108, 126, 127] Kenya[119] England[125]	Norway[108, 126, 127] England[125] United States of America[116]

Table 2: Pooled analysis of injuries in female football for match exposure by participation levels for total exposure hours, number of injuries recorded, injury incident rate per 1,000 match-hrs or Athlete Exposures with 95% confidence intervals, injury definition, estimated costs, and injury probability of one or two injuries occurring per-player per-season.

Level of participation & authors	Exposure hrs	Injury No.	IIR (95% CI)	Injury definition	Estimated costs[1] (NZD$)	Injury probability per player one-season (%)	
						1 injury	2 injuries
Match injuries per 1,000 match/ player-hrs	**363,652**	**8,684**	**23.9 (23.4-24.4)**		**58,897,320**	**100**	**100**
Female Elite	**64,538[bcde]**	**1,882**	**29.2 (27.8-30.5)**		**12,764,251**	**100**	**100**
Engström et al. 1991[13]	2,041	49	0.02 (0.01-0.02)	FI TL	332,332	98.9	98.9
Junge et al. 2004[75]	1,271	62	48.8 (38.0-62.6)	MA TI	420,501	99.5	98.2
Faude et al. 2005[11]	5,115	118	23.1 (18.9-27.2)	FI TL	800,309	100	100
Jacobson et al. 2007[12]	8,345	116	13.9 (11.4-16.4)	FI TL	786,744	100	100
Junge et al. 2007[114]	5,742	387	67.4 (60.7-74.1)	MA TI	2,624,742	100	100
Le Gall et al. 2008[118]	9,795	219	22.4 (19.4-25.3)	FI TL	1,485,319	100	100
Hägglund et al. 2008[9]	7,687	124	16.1 (13.3-19.0)	FI TL	841,003	100	100
Hägglund et al. 2009[112]	1,512	31	20.5 (13.3-27.7)	FI TL	210,251	93	85.8
Gaulrapp et al. 2010[111]	8,382	155	18.5 (15.6-21.4)	FI TL	1,051,253	100	100
Ekstrand et al. 2011[106]	7,540	105	13.9 (11.3-16.6)	FI TL	712,139	100	99.9
Junge et al. 2013[115]	3,564	436	122.3 (110.9-133.8)	FI TL	2,957,074	100	100
Larruskain et al. 2018[117]	3,544	80	22.6 (17.6-27.5)	FI TL	542,582	99.9	99.5
Female International	**9,340[a]**	**206**	**22.1 (19.0-25.1)**		**1,397,150**	**100**	**100**
Waldén et al. 2007[131]	1,314	15	11.4 (5.6-17.2)	FI TL	101,734	59.7	63.5
Sprouse et al. 2020[125]	8,026	191	23.8 (20.4-27.2)	FI TL	1,295,415	100	100
Female Amateur	**100,207[ae]**	**2,403**	**24.0 (23.0-24.9)**		**16,297,819**	**100**	**100**
Östenberg et al. 2000[121]	2,725	39	14.3 (9.8-18.8)	FI TL	264,509	96.2	90.8
Fuller et al. 2007[109]	44,525	946	21.3 (19.9-22.6)	FI TL	6,416,037	100	100
Soligard et al. 2008[17]	16,057	210	12.5 (10.8-14.3)	MA TI	1,424,279	100	100
Tegnander et al. 2008[130]	3,663	89	24.3 (19.3-29.3)	FI TL	603,623	96.6	91.5
Gaulrapp et al. 2010[111]	8,382	155	18.5 (15.6-21.4)	FI TL	1,051,253	100	100
Meyers 2013[120]	13,151	693	52.7 (48.8-56.6)	AII	4,700,120	100	100
Babwah 2014[103]	941	29	30.8 (19.6-42.0)	AII	196,686	91.4	83.8
Owoeye et al. 2017[122]	759	50	65.9 (47.6-84.1)	MA TL	339,114	98.5	95.5
Sprouse et al. 2020[125]	3,037	58	19.1 (14.2-24.0)	FI TL	393,372	99.5	99.5
Horan et al. 2021[113]	6,967	134	19.2 (16.0-22.5)	FI TL	908,826	100	100.0
Female Adolescent	**47,355[ae]**	**1,219**	**25.7 (24.3-27.2)**		**8,267,599**	**100**	**100**
Steffen et al. 2007[132]	40,857	489	12.0 (10.9-13.0)	FI TL	3,316,535	100	100
Soligard et al. 2012[127]	3,036	147	48.4 (40.6-56.2)	MA TI	996,995	100	100
Junge et al. 2013[115]	2,970	455	153.2 (139.1-167.3)	FI TL	3,085,937	100	100
Lislevand et al. 2014[119]	1,318	123	93.3 (76.8-109.8)	MA TI	834,220	100	100
Teahan et al. 2021[129]	89	5	56.2 (6.9-105.4)	FI TL	33,911	36.5	36.5
Female Junior	**142,213[acd]**	**2,974**	**20.9 (20.2-21.7)**		**20,170,501**	**100**	**100**
Andreasen et al. 1993[102]	8,890	361	40.6 (36.4-44.8)	FI TL	2,448,403	100	100
Elias 2001[107]	82,253	1,359	16.5 (15.6-17.4)	ND	9,217,119	100	100
Froholdt et al. 2009[108]	6,349	29	4.6 (2.9-6.2)	AII	196,686	93.6	86.6
Soligard et al 2010[126]	21,893	167	7.6 (6.5-8.8)	FI TL	1,132,641	100	100

Soligard et al. 2012[127]	15,340	624	40.7 (37.5-43.9)	MA TL	4,232,143	100	100
Junge et al. 2013[115]	1,584	225	142.0 (123.5-160.6)	FI TL	1,526,013	99.8	99.8
Lislevand et al. 2014[119]	915	76	83.1 (64.4-101.7)	MA TI	515,453	99.9	99.9
Sprouse et al. 2020[125]	4,989	133	66.9 (55.5-78.2)	FI TL	902,043	100	100
Match injuries per 1,000 AE	**2,924,138**	**15,470**	**5.3 (5.2-5.4)**		**104,997,334**	**-**	**-**
Female Amateur	**504,547[d]**	**8,368**	**16.6 (16.2-16.9)**		**56,795,959**	**-**	**-**
Dick et al. 2007[105]	327,152	5,373	16.4 (16.0-16.9)	FI TL	36,451,936	-	-
Chandran et al. 2021[104]	112,245	1,885	16.8 (16.0-17.6)	FI TL	12,790,253	-	-
Roos et al. 2017[124]	65,150	1,110	17.0 (16.0-18.0)	MA TI	7,532,771	-	-
Female Adolescent	**2,419,591[c]**	**7,102**	**2.9 (2.9-3.0)**		**48,231,671**	**-**	**-**
Khodaee et al. 2017[116]	418,180	2,194	5.2 (5.0-5.5)	FI TL	14,895,680	-	-
Ritzer et al. 2021[123]	2,001,410	4,908	2.5 (2.4-2.5)	FI TL	33,326,694	-	-
Total estimated match costs	**-**	**-**	**-**		**163,894,650**	**-**	**-**

IIR = Injury Incidence Rate; CI = Confidence Interval; FI TL = Full-Inclusive Time-Loss; MA TI = Medical-Attention Treatment-Injury; AII = All-Inclusive-Injury; ND = No-Definition; Significant difference (p<0.05) than (a) = Female Elite; (b) = Female International; (c) = Female Amateur; (d) = Female adolescent; (e) = Female Junior; (1) = costs in New Zealand Dollars (NZD$) based on average cost per accident compensation claim for female football participants[93]

Post FIFA 11+ dissemination there were notably more training injuries (5.2 (95% CI: 5.1 to 5.4) per 1,000 training-AEs) and higher estimated costs (NZD$39,805,201; RR: 1.9 (95% CI: 1.8 to 1.9); *p*<0.0001; *d*=0.58) when compared with pre-FIFA 11+ dissemination (Supplementary Table 9). There were more match injuries recorded post-FIFA 11+ dissemination (3.9 (95% CI: 3.8 to 4.0) per 1,000 match-AEs) and higher estimated costs (NZD$68,480,681; RR: 4.2 (95% CI: 4.1 to 4.4); *p*<0.001; *d*=1.07) (Supplementary Table 10).

For studies reporting per 1,000 match-hrs [9, 11-13, 17, 75, 102, 103, 106-109, 111-115, 117-122, 125-131], the overall pooled match injury incidence for female football players was 23.7 (23.2 to 24.2) per 1,000 match-hrs (Table 2). This varied by participation level with studies on female elite participants reporting more pooled match injuries (29.2 (95% CI: 27.8 to 30.5) per 1,000 match-hrs) than studies reporting on female international (RR:1.3 (95% CI: 1.2 to 1.5); *p*=0.0001; *d*=0.42), amateur (RR: 1.2 (95% CI:1.2 to 1.3); *p*<0.0001; *d*=0.35), adolescent (RR: 1.2 (95% CI:1.1 to 1.3); *p*<0.0001; *d*=0.49), and junior (RR: 1.4 (95% CI:1.3 to 1.5); *p*<0.0001; *d*=0.66) participants. The overall pooled estimated injury probability of one or more injuries occurring during a competition season was 100% for all levels of participation.

The overall pooled injury incidence for studies [104, 105, 116, 123, 124] reporting AE was 5.3 (95% CI: 5.2 to 5.4) per 1,000 AE's (Table 2). This varied by participation level with studies on amateur female football participants reporting an almost six-fold difference in injuries (RR: 5.7 (95% CI:5.5 to 5.8); *p*<0.0001; *d*=0.36) when compared with adolescent female football participants.

Only four studies [103, 104, 120, 130], reported injuries by player groups (Table 3). These were all at the amateur level of participation. Three studies [103, 120, 130], reported player group for match injuries per 1,000 match-hrs with defenders (51.9 (95% CI: 46.3 to 57.4) per 1,000 match-hr.) recording more match injuries than attacker (RR: 1.7 (95% CI: 1.4 to 2.0); *p*<0.0001; *d*=0.56) and midfielder (RR: 1.2 (95% CI: 1.1 to 1.5); *p*=0.0082; *d*=0.23) player groups. One study reported player groups per 1,000 AE's and this was similar with the defenders (18.0 (16.7 to 19.3) per 1,000 AE's) recording more injuries than the attacker (RR: 1.5 (95% CI: 1.3 to 1.6); *p*<0.0001; *d*=0.67) and midfielder (RR: 1.3 (95% CI: 1.1 to 1.4); *p*=0.0001; *d*=1.08) player groups.

A third (38.9%) of included studies [75, 102-107, 114-116, 120, 124], reported injury region but most of these did not report specific injury sites. Studies [75, 102, 103, 106, 107, 114-116, 120], reporting injuries per 1,000 match-hrs showed more pooled injuries for the lower limb (20.5 (95% CI: 19.8 to 21.3) per 1,000 match-hrs) than to chest-back-other (RR: 7.4 (95% CI: 6.6 to 8.2); *p*<0.0001; *d*=1.03), upper limb (RR: 7.0 (95% CI: 6.3 to 7.7); *p*<0.0001; *d*=1.04) and head-neck (RR: 4.0 (3.7 to 4.3); *p*<0.0001; *d*=0.91) body regions (Table 3). Adolescents recorded significantly more injuries to the lower limb (97.0 (95% CI: 85.8 to 108.2) per 1,000 match-hrs) than junior (RR: 8.8 (RR: 7.8 to 10.0); *p*<0.0001; *d*=0.89), amateur (RR: 2.8 (95% CI: 2.4 to 3.2); *p*<0.0001; *d*=1.20), and elite (RR: 2.4 (95% CI: 2.1 to 2.8); *p*<0.0001; *d*=0.74) female participants. This was similar for studies reporting injuries per 1,000-AEs [104, 105, 124]. There were significantly more injuries reported for the lower limb (7.7 (95% CI: 7.6 to 7.9) per 1,000 AEs than the chest-back-other (RR: 4.7 (95% CI: 3.9 to 5.7); *p*<0.0001; *d*=2.28), head-neck (RR: 2.4 (95% CI: 2.2 to 2.6); *p*<0.0001; *d*=1.85) and upper limb (RR: 2.3 (95% CI: 32.2 to 2.4); *p*<0.0001; *d*=2.38) body regions.

Over a third (36.1%) of studies [11, 13, 75, 102, 104-107, 114, 115, 120, 121, 124], reported injury type (Table 3). As not all studies reported all the injuries, the top four most reported injury types (contusions, sprain, strain, concussion) were pooled for analysis. For studies [11, 13, 75, 102, 106, 107, 114, 115, 120, 121], that reported injuries per 1,000-hrs there were significantly more pooled contusions (19.8 (18.6 to 21.0) per 1,000 match-hrs) than sprains (RR: 1.8 (95% CI: 1.3 to 1.5); *p*<0.0001; *d*=0.65), strains (RR: 3.4 (95% CI: 3.0 to 3.9); *p*<0.0001; *d*=1.07) and

Table 3: Summary of pooled analysis of match injuries by total and participation level per 1,000 match-hrs. and per 1,000 competition AE with 95% confidence intervals and number of studies by player role, injury region, top four reported injury type, top four injury mechanisms, injury severity and injury period for included published female football studies.

		Per 1,000 match-hrs						Per 1,000 AE		
		Total	Elite	International	Amateur	Adolescent	Junior	Total	Amateur	Junior
		Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n
Playing position										
	Defender	51.9^{bc} (46.3-57.4)3	N/R	N/R	51.9^{bc} (46.3-57.4)3	N/R	N/R	18.0^{bc} (16.7-19.3)1	18.0^{bc} (16.7-19.3)1	N/R
	Midfielder	41.8^{ac} (36.8-46.8)3	N/R	N/R	41.8^{ac} (36.8-46.8)3	N/R	N/R	14.4^{ac} (13.2-15.6)1	14.4^{ac} (13.2-15.6)1	N/R
	Attacker	41.5^{ab} (35.8-47.3)3	N/R	N/R	41.5^{ab} (35.8-47.3)3	N/R	N/R	16.4^{ab} (15.0-17.9)1	16.4^{ab} (15.0-17.9)1	N/R
	Other/Unknown	N/R	N/R	N/R	N/R	N/R	N/R	0.5 (0.4-0.7)1	0.5 (0.4-0.7)1	N/R
Injury region										
	Head-Neck	5.2^{jkl} (4.8-5.5)8	11.9^{fgh} (10.5-13.4)4	N/R	8.9^{dgh} (7.3-10.4)2	24.9^{dfh} (19.2-30.6)1	2.4^{dfg} (2.1-2.7)3	2.0^{jkl} (1.9-2.1)4	2.2^{h} (2.0-23.)3	1.7^{f} (1.9-1.9)1
	Upper Limb	2.9^{ik} (2.7-3.2)8	5.6^{gh} (4.6-6.6)4	N/R	4.5^{gh} (3.4-5.7)2	11.4^{dfh} (7.6-15.3)1	1.8^{dfg} (1.5-2.1)3	0.5^{ikl} (0.4-0.5)4	0.4 (0.4-0.5)3	0.5 (0.5-0.6)1
	Lower Limb	20.5^{ijl} (19.8-21.3)9	39.8^{fgh} (37.2-42.3)5	N/R	34.9^{dgh} (31.8-38.0)2	97.0^{dfh} (85.8-108.2)1	11.0^{dfg} (10.3-11.7)3	7.7^{ijl} (7.6-7.9)4	10.0^{h} (9.7-10.3)3	5.0^{f} (4.8-5.3)1
	Chest-Back-Other	2.8^{ik} (2.5-3.1)9	4.5^{fgh} (3.6-5.4)5	N/R	2.9^{dgh} (2.0-3.8)2	17.2^{dfh} (12.5-21.9)1	1.9^{dfg} (1.7-2.2)3	0.7^{ijk} (0.7-0.8)4	1.1^{h} (1.0-1.2)3	0.3^{f} (0.2-0.3)1
Injury type										
	Contusion	19.8^{nop} (18.6-21.0)10	18.7^{fghnop} (17.0-20.4)8	N/R	15.4^{dghnop} (13.5-17.4)2	81.5^{dfhnop} (71.2-91.7)1	12.1^{dfgnop} (10.0-14.2)2	2.6^{nop} (2.5-2.7)3	2.6^{nop} (2.5-2.7)3	N/R
	Sprain	10.8^{mop} (9.9-11.7)10	10.5^{ghmop} (9.3-11.8)8	N/R	11.0^{ghmop} (9.3-12.6)2	32.3^{dfhmop} (25.9-38.8)1	5.3^{dfgmop} (3.9-6.7)2	3.7^{mop} (3.5-3.9)3	3.7^{mop} (3.5-3.9)3	N/R
	Strain	5.8^{mno} (5.2-6.5)10	5.6^{fhmnp} (4.7-6.5)8	N/R	8.0^{dhmnp} (6.6-9.4)2	8.4^{hmnp} (5.1-11.7)1	2.3^{dfgmnp} (1.4-3.2)2	5.7^{mnp} (5.5-6.0)3	5.7^{mnp} (5.5-6.0)3	N/R
	Concussion	1.0^{mnp} (0.8-1.2)6	2.2^{hmno} (1.5-3.0)5	N/R	3.3^{hmno} (2.4-4.3)1	3.4^{hmno} (1.3-5.5)1	2.4^{dfgmno} (1.5-3.3)2	1.6^{mno} (1.5-1.7)3	1.6^{mno} (1.5-1.7)3	N/R
	Acute	17.7^{q} (15.6-19.8)1	N/R	17.7^{fq} (14.8-20.6)1	N/R	N/R	20.6^{fq} (16.7-24.6)1	N/R	N/R	N/R
	Gradual	3.2^{r} (2.4-4.1)1	N/R	3.2^{r} (2.0-4.5)1	N/R	N/R	3.8^{r} (2.1-5.5)1	N/R	N/R	N/R
Injury mechanism										
	Player contact	28.7^{nop} (27.2-30.1)8	47.5^{efghu} (43.3-51.8)5	10.2^{dfghu} (8.0-12.4)1	12.3^{deghtuv} (10.9-13.7)4	110.3^{defhu} (99.1-121.5)2	39.1^{defgu} (34.6-43.6)2	7.5^{nop} (7.0-8.0)1	7.5^{nop} (7.0-8.0)1	N/R
	Ball contact	22.1^{mop} (19.5-24.6)1	N/R	N/R	22.1^{suv} (19.5-24.6)1	N/R	N/R	1.6^{mop} (1.4-1.8)1	1.6^{mop} (1.4-1.8)1	N/R
	Non-contact	10.1^{mnp} (9.3-11.0)8	15.4^{efs} (12.9-17.8)5	6.4^{dfghs} (4.6-8.1)1	7.4^{deghst} (6.3-8.5)4	18.1^{efs} (13.5-22.6)2	12.4^{efs} (9.9-14.9)2	2.9^{mnp} (2.5-3.2)1	2.9^{mnp} (2.5-3.2)1	N/R
	Surface contact	7.5^{mno} (6.0-9.0)1	N/R	N/R	7.5st (6.0-9.0)1	N/R	N/R	2.1^{mno} (1.9-2.4)1	2.1^{mno} (1.9-2.4)1	N/R
Injury severity										
	Minor	22.4^{x} (20.9-23.9)6	4.5^{efghx} (3.0-6.0)1	11.6^{dfgh} (9.2-13.9)1	34.3^{deghx} (31.5-37.0)3	111.7^{defhx} (79.0-144.3)1	24.4^{defgx} (20.4-28.4)2	N/R	N/R	N/R
	Missed-Match	11.0^{w} (10.0-12.0)8	11.2^{w} (9.1-13.3)2	12.2 (9.8-14.6)1	11.7^{w} (10.2-13.2)4	2.5^{w} (0.0-7.3)1	9.8^{w} (7.3-12.4)2	N/R	N/R	N/R
Injury period										

	1st Half	16.7 (10.0-23.4)2	26.3[f] (12.0-40.5)1	N/R	11.7[d] (4.8-18.6)1	N/R	N/R	N/R	N/R	N/R
	2nd Half	24.4 (16.3-32.4)2	38.4[f] (21.1-55.6)1	N/R	17.0[d] (8.7-25.3)1	N/R	N/R	N/R	N/R	N/R

* = Numbers reflect papers in study as some reported more than one level of participation; AE = Athlete Exposures; N/R = Not Reported; CI = Confidence Interval; n = Number of studies; Significant difference (p<0.05) than (a) = Defender; (b) = Midfielder; (c) = Attacker; (d) = Female Elite; (e) = Female International; (f) = Female Amateur; (g) = Female Adolescent; (h) = Female Junior; (i) = Head-Neck; (j) = Upper Limb; (k) = Lower Limb; (l) = Chest-Back-Other; (m) = Contusion; (n) = Sprain; (o) = Strain; (p) = Concussion; (q) = Acute; (r) = Gradual; (s) = Player-contact; (t) = Ball-contact; (u) = Non-contact; (v) = Surface-contact; (w) = Minor; (x) = Missed-Match

concussions (RR: 19.8 (95% CI: 16.4 to 23.9); *p*<0.0001; *d*=1.31). For studies reporting injury sites per 1,000-AEs [104, 105, 124], when pooled, strains (5.7 (5.5 to 6.0) per 1,000-AEs) were more commonly reported than sprains (RR: 1.6 (95% CI: 1.5 to 1.6); *p*<0.0001; *d*=0.36), contusions (RR: 2.2 (95% CI: 2.1 to 2.3); *p*<0.0001; *d*=0.77) and concussions (RR: 3.7 (95% CI: 3.4 to 4.0); *p*<0.0001; *d*=0.78).

A quarter (25.0%) of included studies [11, 75, 103, 104, 113, 115, 119, 120, 125], reported on injury cause (Table 3). There were more injuries caused through player contact (28.7 (95% CI: 27.2 to 30.1) per 1,000 match-hrs) than ball contact (RR: 1.3 (95% CI: 1.1 to 1.5); *p*<0.0001; *d*=0.20), non-contact (RR: 2.8 (95% CI: 2.6 to 3.1); *p*<0.0001; *d*=0.68), and surface contact (RR: 3.8 (95% CI: 3.1 to 4.7); *p*<0.0001; *d*=0.72). Adolescents reported more injuries by player contact than elite (RR: 2.3 (95% CI: 2.0 to 2.6); *p*<0.0001; *d*=0.54), junior (RR: 2.8 (95% CI: 2.4 to 3.3); *p*<0.0001; *d*=0.71), amateur (RR: 8.9 (95% CI: 7.7 to 10.4); *p*<0.0001; *d*=0.81), and international (RR: 10.8 (95% CI: 8.5 to 13.7); *p*<0.0001; *d*=0.68) female participants.

Less than a fifth (19.4%) of studies [13, 103, 106, 119-121, 125], reported on injury severity (Table 3). When pooled, there were significantly more minor (22.4 (95% CI: 20.9 to 23.9) per 1,000 match-hrs) than missed-match (RR: 2.0 (95% CI: 1.8 to 2.3); *p*<0.0001; *d*=0.82) injuries reported. This differed by participation level with more missed match injuries than minor injuries at the female elite (RR: 2.5 (95% CI: 1.7 to 3.6); *p*<0.0001; *d*=1.12) level of participation.

Only two [75, 103] (5.6%) of the included studies reported match injury period (Table 3). Although there were more pooled injuries reported in the second half of matches (RR: 24.4 (95% CI: 16.3 to 32.4) per 1,000 match-hrs) than the first half of matches (RR: 1.5 (95% CI: 0.9 to 2.4); *p*=0.1521; *d*=3.08), this was not significant.

For studies [9, 11-13, 17, 106, 108, 110-113, 117, 118, 121, 125-131], reporting incidence of injuries per 1,000 training-hrs, the overall pooled training injury incidence for female football players was 3.6 (95% CI: 3.5 to 3.8) per 1,000 training-hrs. (Table 4). This varied by participation level with studies on junior participants reporting more training injuries (10.1 (9.5 to 10.7) per 1,000 training-hrs) than adolescent (RR: 6.6 (95% CI: 5.5 to 7.8); *p*<0.001; *d*=0.76), amateur (RR: 3.8 (95% CI: 3.5 to 4.1); *p*<0.0001; *d*=0.34) and elite (RR: 2.8 (95% CI: 2.6-3.1); *p*<0.0001; *d*=0.48) female participants.

The overall pooled training injury incidence for studies [104,105,116,124], reporting AE was 3.8 (95% CI: 3.8 to 3.9) per 1,000 AE's (Table 4). This varied by participation level with studies on amateur football participants (5.4 (95% CI: 5.3 to 5.6) per 1,000 AE's) reporting an almost five-fold increase in injuries (RR: 5.1 (95% CI: 4.8 to 5.4); *p*<0.0001; *d*=1.12) compared with junior football participants.

The total estimated costs for the training injuries reported by the included studies were NZD$93,690,416 (Table 4). Female amateur participants accounted the highest costs for studies reporting injuries per 1,000 training-hrs (10.8%; NZD$10,132,726) and per 1,000 training-AEs (65.7%; NZD$61,562,756).

Only one study [104], reported on training injury player positional group (Table 5). The defender (2.3 (95% CI: 2.2 to 2.5) per 1,000 AEs) recorded more injuries than the midfielder (RR: 1.2 (95% CI: 1.1 to 1.4); *p*<0.0001); *d*=1.07) and attacker (RR: 1.5 (95% CI: 1.3 to 1.6); *p*<0.0001; *d*=0.42) player positions.

Five studies [13,104-106,124], reported training injury regions (Table 5). When these studies [13,106], were pooled, the lower limb (4.9 (95% CI: 4.2 to 5.5) per 1,000 training-hrs) recorded significantly more injuries than the head and neck (RR: 12.2 (95% CI: 7.6 to 19.8); *p*<0.0001; *d*=1.23) and chest-back-other (RR: 2.6 (95% CI: 1.1 to 6.2); *p*=0.0278; *d*=1.32). This was similar for those studies reporting training injuries per 1,000 AEs [104,105,124], with the lower limb (3.5 (95% CI: 3.4-3.6) per 1,000 AEs) recording significantly more injuries that the upper limb (RR: 1.9 (95% CI: 1.6 to 2.2); *p*<0.0001; *d*=2.07), chest-back-other (RR: 3.1 (95% CI: 2.8 to 3.5); *p*<0.0001; *d*=1.61) and head-neck (RR: 15.2 (95% CI: 13.7 to 16.8); *p*<0.0001; *d*=2.01) body regions.

Less than a fifth (19.4%) of studies [11,13,104-106,121,124], reported on training injury type (Table 5). When pooled [11,13,106,121], there were significantly more sprains (0.9 (95% CI: 0.7 to 1.2) per 1,000 training-hrs) than other injuries (RR: 1.4 (95% CI: 1.0 to 2.0); *p*=0.0470; *d*=0.19) and concussions (RR: 3.0 (95% CI: 1.7 to 5.4); *p*=0.0001; *d*=1.10) recorded. For studies [104,105,124], reporting AEs when pooled, there were significantly more strains (2.1 (95% CI: 2.0 to 2.1) per 1,000 AEs) when compared with other injuries (RR: 1.6 (95% CI: 1.5 to 1.8); *p*<0.0001; *d*=1.00), sprains (RR: 2.3 (95% CI: 2.2 to 2.5); *p*<0.0001; *d*=0.74) and concussions (RR: 5.2 (95% CI: 4.6 to 5.9); *p*<0.0001; *d*=1.25).

Less than a fifth (12%) of studies [11,113,125], reporting on training injuries reported injury cause (Table 5). When pooled, there were more training injuries caused by non-contact (1.8 (95% CI: 1.5 to 2.0) per 1,000 training-hrs) than player contact (RR: 1.7 [95% CI: 1.4 to 2.1]; *p*<0.0001; *d*=1.40) injuries recorded. This was similar at the amateur [113,125], level with significantly more training injuries caused by non-contact (1.2 (95% CI: 1.0 to 1.5) per 1,000 training-hrs) than injuries caused by player

Table 4: Pooled analysis of injuries in female football for training exposure by participation levels for total exposure hours, number of injuries recorded, injury definition, injury incident rate per 1,000 training-hrs or Athlete Exposures with 95% confidence intervals

Level of participation & authors	Exposure hrs	Injury no.	Injury definition	IIR (95% CI)	Estimated costs[1](NZD$)
Training injuries reported per 1,000 match/player-hrs	**1,011,002**	**3,689**		**3.6 (3.5-3.8)**	**25,019,832**
Female Elite	**274,960[cde]**	**985**		**3.6 (3.4-3.8)**	**6,680,546**
Faude et al. 2005[11]	30,195	84	FI TL	2.8 (2.2-3.4)	569,712
Jacobson et al. 2007[12]	44,815	121	FI TL	2.7 (2.2-3.2)	820,656
Le Gall et al. 2008[118]	87,530	400	FI TL	4.6 (4.1-5.0)	2,712,912
Hägglund et al. 2008[9]	46,469	175	FI TL	3.8 (3.2-4.3)	1,186,899
Hägglund et al. 2009[112]	3,237	12	FI TL	3.7 (1.6-5.8)	81,387
Ekstrand et al. 2011[106]	40,864	118	FI TL	2.9 (2.4-3.4)	800,309
Larruskain et al. 2018[117]	21,850	75	FI TL	3.4 (2.7-4.2)	508,671
Female International	**507[d]**	**3**		**5.9 (0.0-12.6)**	**20,347**
Waldén et al. 2007[131]	507	3	FI TL	5.9 (0.0-12.6)	20,347
Female Amateur	**538,584[ade]**	**1,494**		**2.8 (2.6-2.9)**	**10,132,726**
Engström et al. 1991[13]	4,142	29	FI TL	7.0 (4.5-9.5)	196,686
Östenberg et al. 2000[121]	7,100	26	FI TL	3.7 (2.3-5.1)	176,339
Fuller et al. 2007[110]	280,496	774	FI TL	2.8 (2.6-3.0)	5,249,485
Tegnander et al. 2008[130]	26,956	100	FI TL	3.7 (3.0-4.4)	678,228
Soligard et al. 2008[17]	33,842	113	FI TL	3.3 (2.7-4.0)	766,398
Hägglund et al. 2009[9]	46,469	175	FI TL	3.8 (3.2-4.3)	1,186,899
Gaulrapp et al. 2010[111]	67,056	91	FI TL	1.4 (1.1-1.6)	617,187
Sprouse et al. 2020[125]	46,161	119	FI TL	2.6 (2.1-3.0)	807,091
Horan et al. 2022[113]	26,362	67	FI TL	2.5 (1.9-3.2)	454,413
Female Adolescent	**91,825[abce]**	**145**		**1.6 (1.3-1.8)**	**983,431**
Teahan et al. 2021[129]	264	2	FI TL	7.6 (0.0-18.1)	13,565
Steffen et al. 2008[128]	91,561	143	FI TL	1.6 (1.3-1.8)	969,866
Female Junior	**105,126[acd]**	**1,062**		**10.1 (9.5-10.7)**	**7,202,782**
Froholdt et al. 2009[108]	20,769	9	AII	0.4 (0.2-0.7)	61,041
Soligard et al. 2010[126]	39,402	89	FI TL	2.3 (1.8-2.7)	603,623
Soligard et al. 2012[127]	18,376	771	MA TI	42.0 (39.0-44.9)	5,229,138
Sprouse et al. 2020[125]	26,579	193	FI TL	7.3 (6.2-8.3)	1,308,980
Training injuries per 1,000 AE	**2,643,995**	**10,125**		**3.8 (3.8-3.9)**	**68,670,585**
Female Amateur	**1,668,422[e]**	**9,077**		**5.4 (5.3-5.6)**	**61,562,756**
Dick et al. 2007[105]	1,122,375	5,869	FI TL	5.2 (5.1-5.4)	39,805,201
Roos et al. 2017[124]	203,962	1,161	MA TI	5.7 (5.4-6.0)	7,874,227
Chandran et al. 2021[104]	342,422	2,047	FI TL	6.0 (5.7-6.2)	13,883,327
Female Junior	**975,573[c]**	**1,048**		**1.1 (1.0-1.1)**	**7,107,829**
Khodaee et al. 2017[116]	975,573	1,048	FI TL	1.1 (1.0-1.1)	7,107,829
Total estimated training costs					**93,690,416**

IIR = Injury Incidence Rate; CI = Confidence Interval; AE = Athlete exposure; FI TL = Full-Inclusive Time-Loss; MA TI = Medical-Attention Treatment-Injury; AII = All-Inclusive-Injury; Significant difference (p<0.05) than (a) = Female Elite; (b) = Female International; (c) = Female Amateur; (d) = Female Adolescent; (e) = Female Junior; (1) = costs in New Zealand Dollars (NZD$) based on average cost per accident compensation claim for female football participants93

Table 5: Summary of pooled analysis of training injuries by total and participation level per 1,000 training-hrs. and per 1,000 practice AE with 95% confidence intervals and number of studies by player role, injury region, top four reported injury type, top four injury mechanism, and injury severity for included published female football studies

		Per 1,000 match-hrs						Per 1,000 AE	
		Total	Elite	International	Amateur	Adolescent	Junior	Total	Amateur
		Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n	Rate(95% CI)n
Playing Position									
	Defender	N/R	N/R	N/R	N/R	N/R	N/R	2.3[bc] (2.2-2.5)1	2.3[bc] (2.2-2.5)1
	Midfielder	N/R	N/R	N/R	N/R	N/R	N/R	1.8[ac] (1.7-1.9)1	1.8[ac] (1.7-1.9)1
	Attacker	N/R	N/R	N/R	N/R	N/R	N/R	1.3[ab] (1.2-1.4)1	1.3[ab] (1.2-1.4)1
	Other/ Unknown	N/R	N/R	N/R	N/R	N/R	N/R	0.5 (0.5-0.6)1	0.5 (0.5-0.6)1
Injury region									
	Head-Neck	0.4[jk] (0.2-0.6)1	0.4 (0.2-0.6)1	N/R	N/R	N/R	N/R	0.2[ijk] (0.2-0.3)3	0.2[ijk] (0.2-0.3)3
	Upper Limb	0.3[j] (0.2-0.5)1	0.3 (0.2-0.5)1	N/R	N/R	N/R	N/R	0.1[hjk] (0.1-0.1)3	0.1[hjk] (0.1-0.1)3
	Lower Limb	4.9[hik] (4.2-5.5)2	4.9[hik] (4.2-5.6)1	N/R	4.8 (2.7-6.9)1	N/R	N/R	3.5[hik] (3.4-3.6)3	3.5[hik] (3.4-3.6)3
	Chest-Back-Other	0.2[hj] (0.0-0.3)2	0.1[ehj] (0.0-0.2)1	N/R	0.7[d] (0.0-1.5)1	N/R	N/R	0.7[hij] (0.7-0.8)3	0.7[hij] (0.7-0.8)3
Injury type									
	Sprain	0.9[op] (0.7-1.2)4	0.9 (0.7-1.1)2	N/R	1.4 (0.7-2.1)2	N/R	N/R	0.9[nop] (0.8-0.9)3	0.9[nop] (0.8-0.9)3
	Strain	1.0[op] (0.8-1.2)4	0.9 (0.7-1.2)2	N/R	1.3 (0.7-2.0)2	N/R	N/R	2.1[mop] (2.0-2.1)3	2.1[mop] (2.0-2.1)3
	Other	0.7[mnp] (0.5-0.8)3	0.7 (0.5-0.9)2	N/R	0.6 (0.0-1.1)1	N/R	N/R	0.5[mnp] (0.5-0.6)3	0.5[mnp] (0.5-0.6)3
	Concussion	0.3[mno] (0.1-0.5)1	0.3 (0.1-0.5)1	N/R	N/R	N/R	N/R	0.2[mno] (0.2-0.2)3	0.2[mno] (0.2-0.2)3
	Acute	0.9[r] (0.7-1.1)2	N/R	N/R	0.5[fr] (0.3-0.7)1	N/R	1.5[er] (1.0-2.0)1	N/R	N/R
	Gradual	2.9[q] (2.5-3.3)2	N/R	N/R	1.8[fq] (1.4-2.2)1	N/R	5.0[eq] (4.1-5.8)1	N/R	N/R
Injury mechanism									
	Player contact	1.0[t] (0.9-1.2)4	1.4[ef] (1.0-1.8)1	N/R	0.6[dft] (0.5-0.8)2	N/R	1.7[eft] (1.2-2.2)1	0.9[tuv] (0.8-1.0)1	0.9[tuv] (0.8-1.0)1
	Ball contact	N/R	N/R	N/R	N/R	N/R	N/R	0.6[st] (0.5-0.7)1	0.6[st] (0.5-0.7)1
	Non-contact	1.8[s] (1.5-2.0)4	1.8[ef] (1.3-2.2)	N/R	1.2[ds] (1.0-1.5)2	N/R	3.2[ds] (2.6-3.9)1	1.7[suv] (1.6-1.9)1	1.7[suv] (1.6-1.9)1
	Surface contact	N/R	N/R	N/R	N/R	N/R	N/R	0.6[st] (0.5-0.7)1	0.6[st] (0.5-0.7)1
Injury severity									
	Minor	1.7[x] (1.4-1.9)2	0.8[efx] (0.6-1.1)1	N/R	1.4[df] (1.0-1.7)1	N/R	3.4[de] (2.7-4.1)1	N/R	N/R
	Missed-Training	2.3[w] (2.0-2.6)4	2.1[fw] (1.6-2.5)1	N/R	1.8[f] (1.5-2.2)3	N/R	3.8[de] (3.0-4.5)1	N/R	N/R

* = Numbers reflect papers in study as some reported more than one level of participation; AE = Athlete Exposures; N/R = Not Reported; CI = Confidence Interval; n = Number of studies; Significant difference (p<0.05) than (a) = Defender; (b) = Midfielder; (c) = Attacker; (d) = Female Elite; (e) = Female Amateur; (f) = Female Junior; (h) = Head-Neck; (i) = Upper Limb; (j) = Lower Limb; (k) = Chest-Back-Other; (m) = Sprain; (n) = Strain; (o) = other; (p) = Concussion; (q) = Acute; (r) = Gradual; (s) = Player-contact; (t) = Non-contact; (u) = Ball contact; (v) = Surface contact; (w) = Minor; (x) = Missed-Training

contact (RR: 1.9 [95% CI: 1.3 to 2.7]; p=0.0004; *d*=11.49). Only one study [104], reporting per AE identified injury cause and this was similar with non-contact (1.7 (95% CI: 1.6 to 1.9) per 1,000 training-AEs) recording significantly more injuries than player contact (RR: 1.9 (95% CI: 1.7 to 2.2); $p<0.0001$; *d*=0.63), ball contact (RR: 1.5 (95% CI: 1.3 to 1.8); $p<0.0001$; *d*=0.45) and surface contact (RR: 1.5 (95% CI: 1.2 to 1.7); $p<0.0001$; *d*=0.47).

Less than a fifth (16%) of studies [13,106,121,125], reported injury severity (Table 5). Most [106,125], but not all [13,121], of these studies reported minor injuries as well. When pooled, there were significantly more missed-training (2.3 (95% CI: 2.0 to 2.6) per 1,000 training-hrs) injuries recorded than minor (RR: 1.4 (95% CI: 1.2 to 1.7); $p<0.0001$; *d*=0.16) training injuries.

DISCUSSION

The aim of this systematic review was to examine the incidence, site, type, severity and estimated costs of injuries that occurred from match and training participation in all levels of female football. While some recent reviews have reported incidence of injuries in female football, no pooled analysis for female football has been undertaken. The current pooled analysis incorporates both match and training injuries at all levels of participation from junior to the professional levels of participation.

The principal findings of this study were: 1) total pooled match IIR was 23.7 (95% CI: 23.2 to 24.2) per 1,000 match-hrs and 5.3 (95% CI: 5.2 to 5.4) per 1,000 match-AEs; (2) total pooled training IIR was 3.6 (95% CI: 3.5 to 3.8) per 1,000 training-hrs and 3.8 (95% CI: 3.8 to 3.9) per 1,000 training-AEs; (3) defenders recorded more match injuries; (4) the lower limb recorded the most pooled injuries in both match and training activities; (5) contusions were the most common match injury and strains were the most common training injury; (6) more injuries were recorded as non-contact for match and training activities; (7) the majority of estimated costs (63.6%; $163,973,891) were attributed to match-related injuries.

The majority (72.2%) of studies [9,11-13,17,102,104-106,109-113,115-118,121,123,125,126,128-131], included in this systematic review utilised a full-inclusive time-loss injury definition. A quarter of the studies (25%) utilised either a medical-attention/treatment injury or an all-inclusive injury definition. The use of these definitions was similar however, the all-inclusive injury definition reported on missed-match and missed-training time but excluded injuries that just required assistance from medical personnel. This is problematic as any injury that does not result in a missed-match and takes part in a limited training session may be declared recovered and therefore this is not recorded as an injury [133]. Missed-match definitions also depend upon the duration between matches [133], with some studies reporting on tournaments where matches may occur more than once in a seven-day period or for more than one match a day for consecutive days of the tournament. What constitutes a reliable and accurate injury definition remains a contentious issue [86,87], and this can be seen by the different types of injury definitions reported in this review. The different studies injury definitions and exposure heterogeneity can limit inter-study comparability, and this was evident with one study [107], not reporting an injury definition and five studies [104,105,116,123,124], reporting a different exposure rate (AE).

The estimated costs reported in this study are based on the mean reported costs for moderate to serious claims (MSC) as recorded by the Accident Compensation Corporation (ACC) for female football participants over five years in New Zealand [93]. The classification of MSC means that the injury required additional financial support for treatment, loss of earnings and related medical costs [134,135]. This is not an indication of the injury severity but gives an indication of the impact that the injury has upon the person's life. The costs do not include presentations to a hospital as these are covered by bulk payments made by ACC to the hospitals but do include additional financial support for treatment, loss of earnings and medical-related treatment costs [134,135].

As reported, the majority of the estimated costs (63.6%; $163,973,891) were attributed to match-related injuries. This was not unexpected as most injuries reported were match related. What was unexpected were that female amateurs recorded more estimated training injury costs for studies reporting training injuries per 1,000 training-hrs and training-AEs than female adolescent and female junior participants combined. This may be related to the lower skill level or to a decreased attention to injury prevention such as the FIFA 11+ program [34]. Less than half (41.7%) of the included studies [9,11-13,17,75,102,107,110,114,118,121,130-132], in this systematic review were published before the FIFA 11+ program was disseminated (2009) [136], and the cost of training injuries has reduced by 6.7% ($52,182,862 vs. $48,710,335) reflecting a decrease in the injuries reported (Supplementary Table 9), but the costs of match injuries has increased by 42.6% ($67,524,380 vs. $96,294,811) for female participants (Supplementary Table 10).

To address the injury rate of football, FIFA, through their Medical and Research Centre (F-MARC); America through its Santa Monica Orthopaedic and Sports Medicine Research Foundation (SMSMF) and Norway through the Oslo Sports Trauma Research Centre (OSTRC) combined together and developed the F-MARC, FIFA 11 and FIFA 11+ football injury prevention programmes [137,138]. The most recent edition is the FIFA 11+ and this has been reported [15], to reduce the risk of injury to football players by 30%, but this was undertaken by reviewing studies involving both male and female participants. Of the three female studies [17,128,139], included in the systematic review [15], one study [128], did not detect any differences in injury rates between intervention and control groups of female participants, one study [17], reported on two or more injuries and lower limb only and reported a 32% to 35% decrease in two or more injuries for female participants, and the other study [139], reported there was no difference in the injury risk by study groups. It has also been reported [137,139,140], that, when compared with control groups, none of the FIFA 11 and 11+ injury reduction programmes show any meaningful reduction in overall injury rates for female participants yet, there was a 23% to 31% injury reduction rate in male participants.

The foundation for the FIFA 11+ was undertaken using male senior football players [141], and junior male players [142], utilising a 2-week injury duration full-inclusive time-loss injury definition. Although females participate in match activities under the same rules as males, females reportedly have higher injury risks, even though they have lower physiological indices (e.g., reduced speed and less agility, lower muscular power, lower estimated maximal aerobic power) when compared with men [143]. More recently there has been a call for research efforts to be directed towards development of an evidenced based framework towards an understanding of female physiological, training, injury and illness surveillance data [144,145]. This is warranted in the regards to injury prevention programs such as the FIFA 11 and 11+ to be researched and developed specifically for female participants.

Previous epidemiological studies have reported that the match injury incidence rate (IIR) of female participation that varied from 13.9 [106], to 91.8 [115], per 1,000 match-hrs with a pooled IIR of 42.7 per 1,000 match-hrs [146]. This is higher that the pooled match IRR reported for this study (23.7 (95% CI: 23.2 to 24.2) per 1,000 match-hrs and 5.3 (95% CI: 5.2 to 5.4) per 1,000 match-AEs). This was similar with training injuries with females having a training IIR range of 2.3 [131], to 3.8 [9], per 1,000 training-hrs with a pooled IIR of 3.4 per 1,000 training-hrs [146]. This is similar to the pooled training IRR reported for this study (3.6 (95% CI: 3.5 to 3.8) per 1,000 training-hrs and 3.8 (95% CI: 3.8 to 3.9) per 1,000 training-AEs). The main difference between these studies was that the previous pooled studies were limited to one junior [127], and eight elite [9,106,112,115,117,131,147,148], level of participation studies.

This was similar when conducting the backward citation tracking [76], on the systematic reviews, when combining the references that met the different systematic reviews inclusion criteria, there was only one published paper [17], that was included in three [18,34,35], of the systematic reviews. There were five [11,111,121,130,131], published papers in two [30,39], of the systematic reviews but when comparing the systematic reviews for elite female football [7, 39], only one paper [52], was included in both of reviews but this paper did not meet the criteria to be included in this systematic review and pooled analysis.

An interesting finding was that more than half (61.1%) of the included studies [11-13,102-104,106-108,111-113,116-118,124-127,129-131], reported the injuries as a total, or overall, IIR by combining the match and training exposure and injury data. Although these papers also reported the match and training IIR, the combining of the data can be misleading as the results depend upon the ratio of training to match exposures and of the injury incidence during match and training activities [85]. The end result is the masking of the higher IIR during matches giving a false representation of the IIR that is occurring [85].

Not all included studies differentiated match injuries [149,150], or as male from female participants [151] and these studies were excluded from the full pooled analysis. The lower limb was the most commonly reported injury region across all levels of participation in both male and female participants [39,40,114,130], with females having a reported 66% [114], to 89% [131], of injuries to the lower limbs. This finding may be related to females having a reportedly lighter and wider pelvis and larger subpubic angle [152], This difference in female may result in the transference of destabilizing forces that occur from sports participation to the lower extremities enhancing the transmission of these loading forces to this area [152,153]. Other suggestions as to the reasons for the higher incidence in lower limb injuries in female footballers are anatomical, increased joint laxity, less trunk and lower extremity neuromuscular control, hormonal regulation, and different biomechanics when compared with male footballers [154-156]. However, due to the lack of epidemiological data from studies reporting on female football players for joint and ligament injuries and specific injury sites, any sub-analysis focusing on these aspects was unable to be completed. Despite this, studies have reported that female team sports participants have a two-to-six-fold [117,157,158], higher likelihood of suffering an anterior cruciate ligament tear and a two-to-five-fold [117], likelihood of suffering a severe ankle sprain when compared with male team sports participants and the most frequently injured body parts are the knee (12-34%), ankle (9-35%) and thigh (11-27%) [159].

The most commonly reported pooled injury types for female football matches were contusions and muscle sprains. This is similar with previous studies [3,7,39,40], that have reported that quadricep, hamstring strains and ankle sprains were the most frequent injuries diagnosed in football players. It has been suggested [160], that this is related to kicking as female show a lower iliacus activation when compared with males during ball kicking [161]. Therefore, due to strength differences of male and female players whilst using the same ball (dimension and weight) it may lead to an increased incidence of lower leg injuries occurring [162,163].

There has been an increased focus on head injuries in all sporting environments [164-166], and previous studies have shown that female football have a higher concussion rate overall (RR = 1.83; 95% CI, 1.34-2.51), during match competitions (RR = 2.00; 95% CI, 1.35-2.96), but not during training activities (RR = 1.22; 95% CI, 0.72-2.09) when compared with men's football concussion rates.[167] Although the reported incidence of concussion (1.0 per 1,000 match-hrs; 1.6 per 1,000 match-AEs) in this systematic review and pooled analysis is higher to other systematic reviews (0.1[18], to 0.2 [3], per 1,000 match-hrs; 0.27 [122], per 1,000-AEs), this study incorporated all levels of participation not just elite or youth female participants.

The low incidence of concussion may be related to inconsistencies in the interpretation and reporting of the symptoms of concussion [168], the knowledge of the team management about what a concussion is and player willingness to report as well as available medical support for female football at all levels of participation [169]. Future research is recommended to identify team management knowledge and player awareness of, and towards, concussion.

A limitation to this study was that only published, and peer-reviewed literature were included. Typically, most of the studies included in this review were undertaken over a single season or competition, limiting the identification of injury trends, and future longitudinal studies should be encouraged in female football activities at all levels of participation. Another limitation that limits inter-study comparisons are the different injury definitions, methodological approaches and reporting modalities that were utilised and some, but not all, studies were completed over a single season or competition, and this can limit the identification of injury trends, and future longitudinal studies should be encouraged in female football activities. As previously reported, nearly half (47.2%) of studies [9,11-13,17,102,106,108,111,112,117,118,121,126-128,130], were from Europe based teams, and a quarter (25.0%) were from the United States of America [104,105,107,109,110,116,120,123,124], but there were no southern hemisphere studies reporting on female football. The lack of southern hemisphere female football studies reduces the generalisability of the findings reported in this systematic review. Studies reporting on female football in the southern hemisphere are recommended to enable comparisons to be completed.

CONCLUSIONS

Most studies included in this systematic review utilised a full-inclusive time-loss injury definition. The total pooled match IIR was 23.7 per 1,000 match-hrs and 5.3 per 1,000 match-AEs while the total pooled training IIR was lower at 3.6 per 1,000 training-hrs and 3.8 per 1,000 training-AEs. The majority of the estimated costs (63.6%; $163,973,891) costs were attributed to match-related injuries. Due to the lack of epidemiological data from studies reporting on female football players for joint and ligament injuries and specific injury sites, any sub-analysis focusing on these aspects was unable to be completed. Future research is recommended to identify team management knowledge and player awareness of, and towards, concussion. The finding that most studies were from Europe based teams and there were no southern hemisphere studies reporting on female football is a limitation to these results and reduces the generalisability of the findings of this systematic review. Studies reporting on female football in the southern hemisphere are recommended to enable comparisons to be completed. Injury prevention interventions need to focus on female junior football players to reduce lower limb injuries and contusions.

COMPLIANCE WITH ETHICAL STANDARDS

Conflicts of Interest

Doug King, Patria Hume, Trevor Clark, Karen Hind, and Daniel Glassbrook declare that they have no conflicts of interest relevant to the content of this review.

Author Contributions

i. Contributor statement: According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed above qualify for authorship based on making one or more of the substantial contributions to the intellectual contConception and design (DK, TC); and/or

ii. Acquisition of data (DK); and/or

iii. Analysis and interpretation of data (DK, TC, DG); and/or

iv. Participated in drafting of the manuscript (DK, PH, TC, KH, DG); and/or

v. Critical revision of the manuscript for important intellectual content (DK, PH, TC, KH, DG); and

vi. All authors read and approved the final manuscript

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