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Review

Sex differences in injury rates in team-sport athletes: A systematic review and meta-regression analysis

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Abstract

Background: Team-sport players have a particularly high injury risk. Although female sex is considered a risk factor, it is still unknown whether female and male team-sport players, in fact, differ in their injury rates. We aimed to compare injury rates between female and male players by systematically reviewing and meta-analyzing injury surveillance studies of both sexes in order to evaluate sex-specific differences in team-sport injuries.

Methods: Studies that prospectively collected injury data for high-level female and male players (age ≥16 years) in basketball, field hockey, football (soccer), handball, rugby (union and sevens), and volleyball were included. Two reviewers (AZ and ALR) independently assessed study quality and extracted data for overall, match, training, and severe injuries (>28 days' time loss) as well as data regarding injury locations and types. Incidence rate ratios (IRRs) were pooled in a meta-analysis, and meta-regression analysis was performed when 10 or more studies were available.

Results: Of 20 studies, 9 studies reported injury data from football, 3 studies from rugby, 3 studies from handball, 1 study from basketball, 1 study from field hockey, 2 studies from volleyball, and 1 study from basketball and field hockey. For overall injuries, the pooled IRR = 0.86 (95% confidence interval (95%CI): 0.76−0.98) indicated significantly more injuries in male than in female players. For injury location, the pooled IRR showed higher injury rates in male athletes than in female athletes for upper extremity, hip/groin, thigh, and foot injuries. Female players had a significantly higher rate of anterior cruciate ligament injuries (IRR = 2.15, 95%CI: 1.27−3.62) than male players. No significant sex-specific differences in IRR were found for match, training, severe injuries, concussions, or ankle sprains.

Conclusion: Our meta-analysis provides evidence for sex-specific differences in the injury rates in team sports. Further epidemiological studies including both sexes in sports other than football are needed in order to strengthen the evidence.

Keywords: Athletes; Female; Injuries; Male; Team sports

1. Introduction

In recent years, sports injuries have been extensively researched in terms of their incidence, risk factors, and prevention measures. Team-sport athletes appear to be at particularly high risk of injury[1] due to the complex characteristics of their games, which usually include varied movements and interaction with the ball, team-mates, and opponents. The pooled incidence rates of match injury are about 36 injuries per 1000 exposure hours in elite male football (soccer)[2] or 81 injuries per 1000 exposure hours in elite male rugby.[3] However, specific injury rates vary according to circumstances, such as injury definition (time loss or all medical attention),[4] age level and type of exposure (match or training, tournament or season). Numerous studies that include seasonal injury rates for football and rugby exist, but fewer data are available for other team sports, such as basketball, volleyball, handball, and

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ice and field hockey. Data from the 2012 and 2016 Olympic Games indicate that the percentages of injured players in handball (females: 10.7% and 26.3%; males: 17.4% and 18.0%) and field hockey (females: 9.4% and 17.2%; males: 17.3% and 18.0%) are almost as high as in football (females: 14.8% and 45.0%; males: 13.2% and 27.0%) and rugby (females: 15.3%; males 21.1% (2016 only)).[5,6]

A frequently overlooked aspect of epidemiological injury data is sex-specific differences. Systematic reviews and meta-analyses in recent years[7−9] indicate a higher risk of ankle sprain,[7] concussion,[8] and anterior cruciate ligament (ACL) injury[9] in females. Although these reviews include a large number of studies, no sport-specific data are reported. Also, study samples vary, with some including a mixture of professional, (semi)amateur, collegiate, high school, and recreational and military athletes from various sports. One recently published meta-analysis shows a different risk for running-related injuries between females and males.[10] However, no such data exist for team sports. Another problem that may have more serious consequences for the interpretation of pooled data is the lack of differentiation among studies with differing injury definitions or periods of data collection (tournament *vs*. season). Comparing pooled data of surveillance studies that were carried out with males or females only may lead to an increased risk of bias.[4,11,12] As a consequence, it remains uncertain whether reported sex differences in injury incidence rates are caused by differences in injury definition, data collection, and/or sample characteristics.

Epidemiological studies reporting injury rates for both females and males during a single season using the same methods are rare,[13−15] and results are inconclusive. For example, 2 studies on injuries in elite football[13,14] agreed on a higher overall, training and match injury incidence in men (7.7[14] and 8.3[13] per 1000 h) compared to women (5.5[14] and 6.3[13] per 1000 h). However, severe injuries were similar for both sexes in one study (both 0.7 per 1000 h),[14] whereas the other study reported a higher incidence in women (1.42 per 1000 h) compared to men (0.95 per 1000 h).[13] In both studies,[13,14] the severity of injuries was defined as time loss of more than 28 days, which raises the question of whether females may be predisposed to injuries that require a long-term healing process and/or postoperative recovery period, such as ACL ruptures.[16] It is also mostly unclear whether sex-specific anatomical or physiological aspects contribute to differences in joint laxity or sensorimotor control mechanisms[17,18] and may, therefore, influence the risk of specific injury characteristics involving the ligament, tendon, or muscles.

Altogether, the current state of knowledge regarding sex-specific differences of injuries in team sports is influenced largely by studies conducted under particular circumstances and with a particular methodology, often with only one sex or the other. Therefore, the present study performed a meta-analysis to compare injury rates of both sexes in elite adult or youth team sports. To avoid systematic bias in data pooling, only studies with data for both sexes were included. Potential moderators in terms of competition characteristics (tournament *vs*. season), injury definition, or age level were considered using meta-regression analysis.

2. Methods

A systematic review with meta-analysis and meta-regression was conducted according to the Meta-analyses of Observational Studies in Epidemiology guidelines.[19] A review protocol is registered at the University of York, Centre for Reviews and Dissemination PROSPERO database: Registration No. CRD4201911883 (http://www.crd.york.ac.uk/prospero/).

2.1. Data search and selection criteria

Systematic database searches were performed through February 2021 using PubMed, Web of Science, and Google Scholar. For these, the term “injuries” was combined (AND) with “football” OR “soccer” OR “basketball” OR “handball” OR “volleyball” OR “rugby” OR “hockey”. Additionally, manual searches were performed of relevant systematic reviews and meta-analyses[2,7−9] as well as reference lists within reviewed articles. The literature search was conducted by 2 researchers (FN and DP) with the assistance of 2 experienced researchers (ALR and AZ).

Studies involving a prospective cohort design were included if they reported (1) injury and exposure data, (2) the data for both female and male athletes, and (3) the data in one of the following Olympic team sports: basketball, field hockey, football, handball, rugby union or rugby sevens, and volleyball. These sports were chosen because they typically include multiple jump-landing, side-cutting, and change-of-direction movements, which are thought to be primarily responsible for noncontact injuries.[20,21] Studies were considered relevant if they (1) were published in the English, Spanish, or German language, (2) appeared in peer-reviewed journals, (3) reported acute and/or overuse injuries, (4) took place during tournaments or playing seasons, (5) were published after the year 1998, (6) performed a surveillance of players ≥16 years old, and (7) reported injuries in a high-level or collegiate league or in major senior or youth tournaments. Studies with data collection before 1998 were excluded in order to avoid the issue of changing physical demands in team sports over the past 2 decades,[22,23] which could influence the injury rate ratio between sexes.

Exclusion criteria related to insufficient data reporting included a lack of sex-specific data on injury and/or exposure, missing age in collegiate or youth players, and no specific team sport mentioned. Studies with a retrospective or media-based data analysis were also excluded. Injury reports from central databases (e.g., National Collegiate Athletic Association) were excluded due to the lack of detailed information about the study sample (e.g., age) as well as in order to avoid duplicate injury data from the same surveillance period as reported in various studies. Studies of nonprofessional, semiprofessional, military, or high-school players under the age of 16 were also excluded. Eligible studies of the same team sport were carefully checked for potential overlaps in sample and surveillance period (e.g., same tournaments or seasons). In cases of overlap,[24,25] the study with the longer time period or greater amount of data was chosen.

2.2. Data extraction

Data were extracted independently by 3 authors (ALR, DP, and AZ) for football and by 2 authors (AZ and FN) for all other sports. The following information was retrieved: sample size, sample characteristics (age level, nationality of players), year (s) of data collection, exposure data for female and male players, tournament and/or season, and injury definition (time loss, all medical attention, or any physical complaint). Extracted injury data were overall, match, training, severe, head, upper extremity, trunk, hip/groin, thigh, knee, ankle, and foot injuries as well as sprains, strains, concussion, ankle sprains, hamstring injuries, and ACL and Achilles tendon ruptures. Retrieved exposure data were exposure hours and athletic exposure. Discrepancies between authors were resolved by consensus. Severe injuries were defined by a time loss of 28 or more days[26] following the injury.

2.3. Assessment of study quality

Two authors (ALR and AZ) independently assessed the methodological quality of included studies. A rating scale was developed based on other scales for quality assessment.[8,27,28] The 19 items with a maximum possible score of 30 points were: inclusion criteria, participant recruitment, players' characteristics, season and/or tournament data, exposure assessment (4 items), frequency of data recording (2 items), injury definition (2 items), injury data collection (2 items), injury details (2 times), data reporting (2 items), and drop-out (for details, see Supplementary Table 1). The scoring for each study was summed for the total quality score. Disagreements between raters were resolved by consensus. For discrepancies that could not be resolved, a third author was consulted (DP for football, FN for all other sports). Publication bias was checked by visual inspection of funnel plots (incidence rate ratios against standard errors).

2.4. Statistical analysis

Injury data were analyzed using R software (Version 4.0.5; The R Core Team, Vienna, Austria) for meta-analysis and meta-regression.[29] Injury outcomes were (1) all injuries; (2) match injuries; (3) training injuries; (4) severe injuries; (5) injuries of the head, upper extremities, trunk, hip/groin, thigh, knee, ankle, and foot; (6) sprain and strain; (7) concussion, ankle sprain, ACL rupture, and Achilles tendon rupture.

The injury incidence rate ratio (IRR) between females and males with corresponding 95% confidence intervals (95%CIs) was calculated. The following equation was used for IRR calculation: (number of injuries of female athletes/exposure hours of female athletes)/(number of injuries of male athletes/exposure hours of male athletes). Only exposure hours were considered for the calculation because none of the included studies used other (athletic) exposure quantifications. The IRR resembles a ratio of the sex-specific (female/male) injury incidence rates. Consequently, a value smaller than 1 indicates a higher injury risk in males, and the closer the value is to 0, the larger is the difference in females. Meta-analysis included random effects based on a Mantel-Haenszel method for dichotomous data. A pooled estimate for the IRR was calculated for each outcome with two or more studies and summarized in a forest plot. Heterogeneity was assessed using the I^2 statistic.[30]

Meta-regression analyses were performed via the functions metainc and metareg from the R package meta[31] for each outcome for which 10 or more studies were available[32] in order to identify moderators that influenced the pooled estimates of the meta-analyses.[33] These categorial moderators were methodological characteristics that could potentially lead to an increased risk of bias[4,12] and that were reported consistently in the studies. They include (1) type of exposure (tournament *vs.* season), (2) injury definition (time loss *vs.* all medical attention/physical complaints),[34] (3) age level (senior *vs.* collegiate/youth players), (4) type of sports (football *vs.* rugby, basketball, handball, volleyball, or field hockey, respectively), and (5) study quality ($\geq$80% *vs.* $<$80%, cut-off representing the approximate median). The moderator "type of sports" had not 2 levels (like the other moderators) but 6 levels (one for each sport), so the level with the largest number of studies (football) was defined as the reference level. The reference level was then compared with each other sport.

3. Results

3.1. Search results

A total of 19,388 references in the 6 team sports were identified in the database search (Fig. 1). Of those, 4482 duplicates or noneligible language studies were excluded (21%). Another 14,379 studies were eliminated after reading the title and abstract. After full-text screening, 507 additional studies were excluded because they (1) did not report exposure data or required sample characteristics, (2) had no clear injury definition, or (3) collected data retrospectively or by using central databases. Finally, data from the remaining 20 studies were used for the qualitative and quantitative analyses. Two studies, from Bere et al.[35] and Soligard et al.,[36] reported data from players in different age groups. The groups not meeting our age limit ($>$16 years) were excluded. Overlaps in injury data reporting were observed for Junge et al.[24] and Langevoort et al.,[25] resulting in the exclusion of the 2004 Handball Olympics data from Junge et al.[24]

3.2. Characteristics of included studies and methodological quality

Included studies collected injury and exposure data between 1998 and 2017 and were published between 2004 and 2020. Nine studies reported injury data from football,[13,14,36–42] 3 studies from rugby union/sevens,[43–45] 3 studies from handball,[25,46,47] 1 study from basketball,[48] 1 study from field hockey[49], 2 studies from volleyball,[35,50] and 1 study from basketball and field hockey.[24] Thirteen studies presented in-season data,[13,14,37,40,42–50] and 7 studies presented tournament data (Olympic Games, World Cup, European Championships, and National Cup).[24,25,35,36,38,39,41] The majority of studies investigated senior athletes ($n = 16$ studies),[13,14,24,25,35,37,39–42,45–50] 5

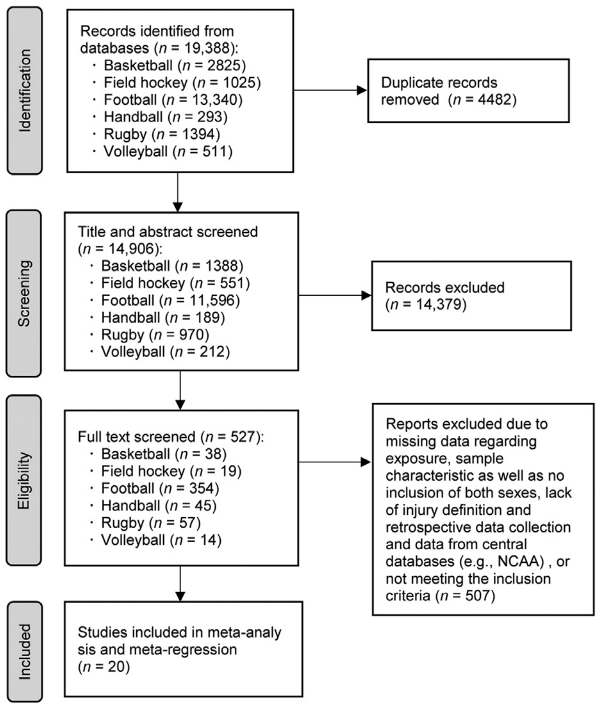

Fig. 1. PRISMA flow diagram of the identification and selection of the studies included in this meta-analysis. NCAA = National Collegiate Athletic Association; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

studies youth[36,38,39,47,49] and 2 studies collegiate[43,44] athletes. All studies collected data for both acute and overuse injuries. Seventeen studies[13,14,24,25,37–43,45–50] collected data from a total of 8855 female and 16,317 male athletes. Three studies[35,36,44] had no information on the sample size but reported injury rates in a manner consistent with our methods. Exposure data in all included studies were presented in hours. The reported exposure time for match and training together was 391,250 h (match exposure: 107,915 h) for female players and 832,383 h (match exposure: 191,316 h) for male players. Injury was defined by time loss in 13 studies[13,14,37,38,40–43,45,47–50] and by medical attention in the remaining 7 studies.[24,25,35,36,39,44,46] Details regarding sample characteristics, exposure, and injury data for each study are summarized in Supplementary Table 2.

The quality score of the 20 studies ranged between 19 and 28 out of a maximal 30 points, with a mean ± SD score of 24.5 ± 2.7 points. The 9 studies published before 2010 had a mean quality score of 25.3 points, and the 11 studies published after 2010 had a mean quality score of 24.0 points. The complete quality scores for each study are presented in Supplementary Table 1. Visual inspection of funnel plots (Supplementary Figs. 1 and 2) indicated no publication bias.

3.3. *Injury incidence, meta-analyses, and meta-regression*

3.3.1. *Overall injuries*

The reported incidence of overall (match and training) injuries varied between a minimum of 2.4 (females)[50] and 3.8 (males)[50] per 1000 h in volleyball and a maximum of 40.8 (females)[45] and 45.0 (males)[45] per 1000 h in rugby. Six studies[13,14,37,38,41,42] of football players reported overall injury rates between 4.6 and 9.9 per 1000 h for female players and between 6.4 and 9.5 overall injuries per 1000 h for male players. Two studies[43,45] of rugby reported overall injury rates of 20.1 and 40.8 per 1000 h for females and 17.7 and 45.0 per 1000 h for males. No multiple overall injury data were available for any of the other sports.[47–50]

The overall injury IRR between females and males was 0.86 (95%CI: 0.76–0.98; $I^2 = 73\%$), indicating a higher injury rate in male players (Fig. 2). The meta-analysis of subgroups showed that this effect was statistically significant for football (IRR = 0.75, 95%CI: 0.71–0.80; $I^2 = 0\%$) and handball (IRR = 0.76, 95%CI: 0.61–0.96; $I^2 = 0\%$) but not for the other team sports.

The meta-regression confirmed that the pooled IRR is partially moderated by the type of sport. Basketball (regression coefficient estimate = 0.835, 95%CI: 0.562–1.109; $z = 5.99$; $p < 0.001$) and rugby (estimate = 0.255, 95%CI: 0.028–0.482; $z = 2.20$; $p = 0.028$) significantly differed from football in the sex-specific distribution of injury rates (reference level in the model). Moreover, no significant moderators of the IRR between females and males were found for tournament *vs.* season (estimate = −0.263, 95%CI: −0.660 to 0.134; $z = -1.30$; $p = 0.194$), age level (estimate = −0.025, 95%CI: −0.334 to 0.283; $z = -0.161$; $p = 0.872$), and study quality (estimate = −0.030, 95%CI: −0.165 to 0.105; $z = -0.440$; $p = 0.660$).

3.3.2. *Match injuries*

Seventeen studies[13,14,24,25,35–39,41,43,44,46–50] reported match injury incidences with a range of 4.2[50] to 110.5[25] per 1000 h for females and 3.8[50] to 113.0[25] per 1000 h for males. The lowest incidences in both sexes were found in volleyball[50] and the highest in handball.[25] Seven studies[13,14,36–39,41] of football players reported between 13.9[37] and 91.8[39] match injuries per 1000 h for female players and between 22.1[37] and 83.4[39] match injuries per 1000 h for male players. In 3 studies of handball,[25,46,47] the match injury incidences were between 13.0[47] and 110.5[25] per 1000 h for females and 17.2[47] and 113.0[25] per 1000 h for males. In 2 rugby studies,[43,44] the match injury incidences were 17.0[44] and 55.6[43] per 1000 h for females and 16.9[44] and 46.4[43] per 1000 h for males. In 2 volleyball studies,[35,50] the match injury incidences were 4.4[50] and 12.2[35] per 1000 h for females and 3.8[50] and 11.7[35] per 1000 h for males. In 2 field hockey studies,[24,49] the match injury incidences were 9.6[49] and 14.5[24] per 1000 h for females and 9.5[49] and 46.8[24] per 1000 h for males. In 2 other basketball studies,[24,48] reported injuries per 1000 h were 55.3[48] and 100.1[24] for females and 46.8[48] and 96.5[24] for males.

The pooled IRR (0.90, 95%CI: 0.78–1.03; $I^2 = 80\%$) for all sports showed no significant differences between sexes (Fig. 3). Furthermore, the subgroup analysis identified no significant sex-specific differences in the match injury rates in any single team sport. No significant moderators were found for the match injury IRR between females and males in the meta-regression analysis.

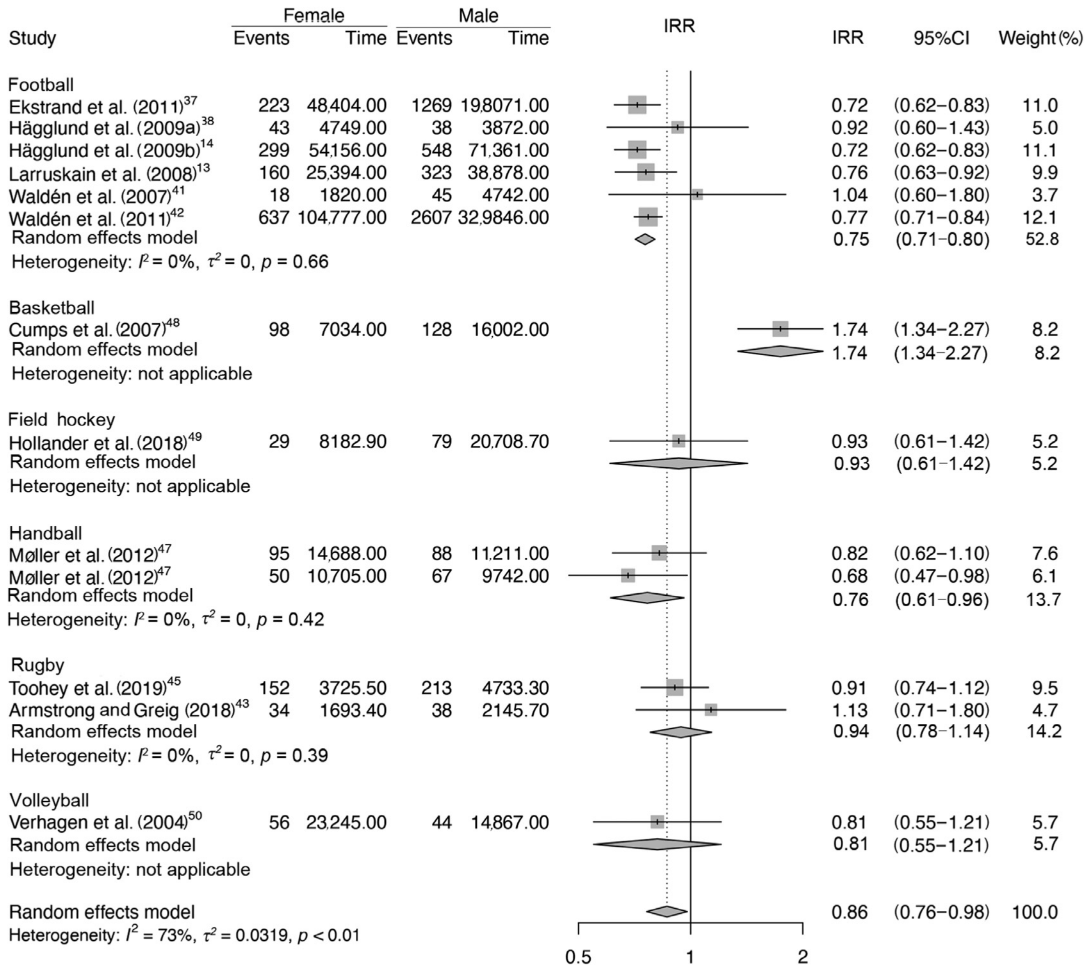

Fig. 2. Forest plot with the pooled incidence rate ratios (IRRs) and 95% confidence intervals (95%CI; lower limit to upper limit) of the female *vs*. male comparisons for overall injuries.

3.3.3. *Training injuries*

The injury incidence rates during training in all team sports ranged between 1.5[50] and 5.8[43] per 1000 h for females and 1.3[38] and 5.3[43] per 1000 h for males. Five studies[13,14,37,38,41] of football players reported between 2.3[41] and 3.8[14] training injuries per 1000 h for female players and between 1.3[38] and 4.7[38] training injuries per 1000 h for male players. Two studies[46,47] with data on training injuries in handball reported an incidence of 2.1[47] and 4.1[46] training injuries per 1000 h for females and 3.2[46] and 3.4[47] per 1000 h for males. No multiple training injury data were available for any of the other sports.[43,48–50]

The meta-analysis (Fig. 4) resulted in a pooled random effect IRR of 0.87 (95%CI: 0.75−1.00; $I^2 = 32\%$). In the meta-regression analysis, injury definition was the only significant moderator (estimate = −0.57, 95%CI: −1.12 to −0.01; $z = -2.00$; $p = 0.045$) of sex-specific differences in training injuries.

3.3.4. *Severe injuries*

Eight studies[13,14,24,25,35,37,38,41] reported data for severe injuries. The incidence rate ranged from 0.6[37] to 3.6[24] per 1000 h for female players and from 0.7[14,37] to 7.2[24] per 1000 h for male players. The pooled IRR among all team sports was 0.96 (95%CI: 0.77−1.20; $I^2 = 0\%$). Most included studies with severe injury data concerned football players and showed an average incidence of 0.8 in both sexes (female: 0.6[37]−1.6[41] per 1000 h; male: 0.7[37]−2.5[41] per 1000 h). No subgroup analysis or meta-regression was performed for the other sports because of the low number of studies.

3.3.5. *Location of injuries*

Nine studies[13,14,24,25,37,41,44,45,49] reported the incidence of thigh and foot injuries, and 10 studies[13,14,24,25,37,41,43–45,49] reported head, upper extremity, trunk, hip/groin, knee, and ankle injuries. The IRR and meta-regression data for the various body locations in all team sports are shown in Table 1. The pooled IRR showed significantly more injuries in male players than female players for the upper extremity (IRR = 0.75, 95%CI: 0.57−0.99; $I^2 = 30.3\%$), hip/groin (IRR = 0.60, 95%CI: 0.41−0.88; $I^2 = 41.5\%$), thigh (IRR = 0.69, 95%CI: 0.58−0.81; $I^2 = 0\%$), and foot (IRR = 0.64, 95%CI: 0.46−0.88; $I^2 = 0\%$).

The meta-regression identified age level (senior *vs.* youth/collegiate) as a significant moderator for the hip/groin IRR (estimate = −2.00, 95%CI: −3.72 to −0.20; $z = -2.18$;

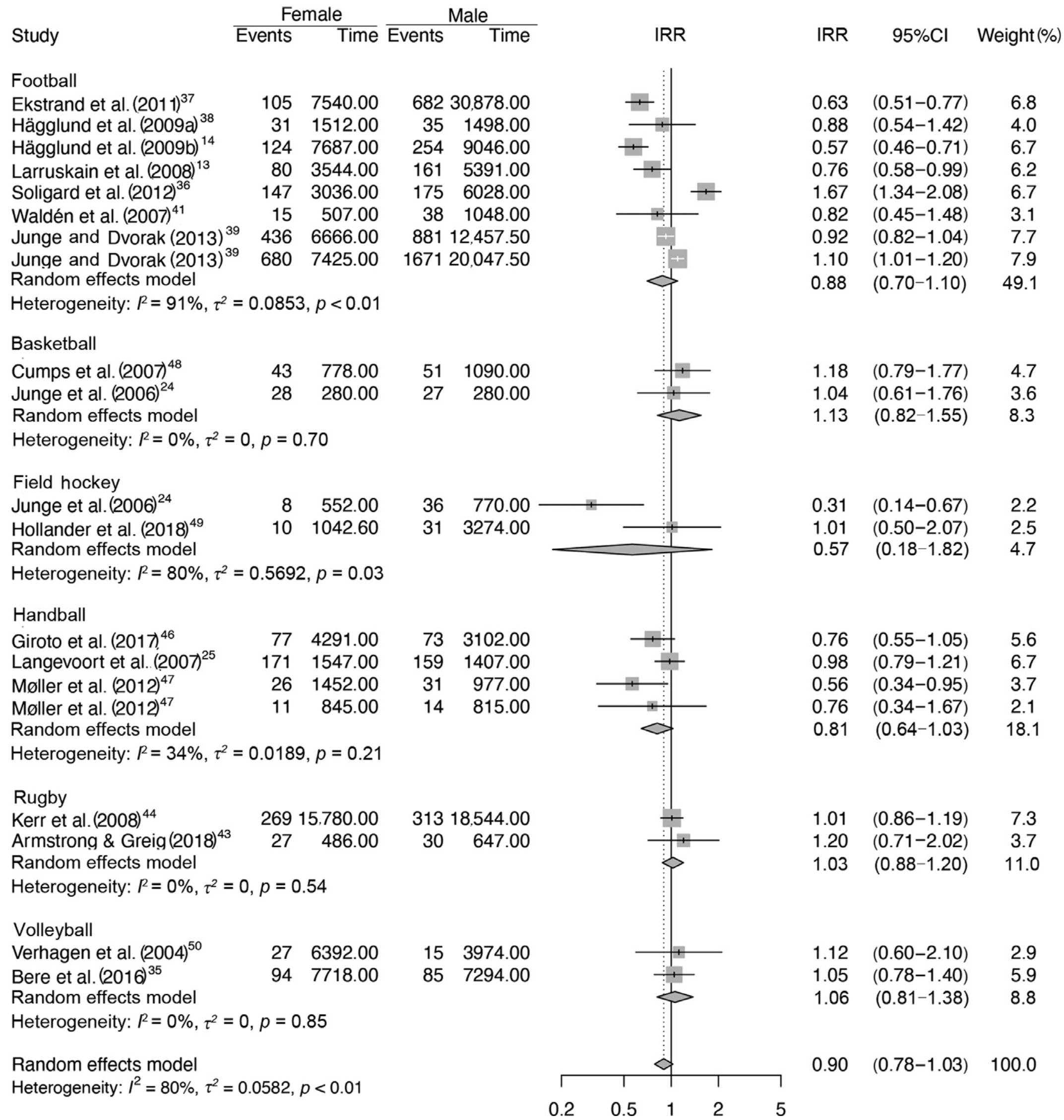

Fig. 3. Forest plot with the pooled incidence rate ratios (IRR) and 95% confidence intervals (95%CIs; lower limit to upper limit) of the female *vs.* male comparisons for match injuries.

$p = 0.029$). The type of sport was a significant moderator for upper extremity (football *vs.* field hockey: estimate = 1.08, 95%CI: 0.04−2.11; $z = 2.04$; $p = 0.041$), trunk (football *vs.* rugby: estimate = 1.42, 95%CI: 0.37−2.46; $z = 2.67$; $p = 0.008$), and hip/groin injuries (football *vs.* rugby: estimate = 1.57, 95%CI: 0.67−2.47; $z = 3.43$; $p = 0.001$) (Table 1). No volleyball studies were included in the meta-regression analysis.

3.3.6. Injury types and diagnosis

Data on sprains were available in 9 studies[14,24,25,37,41,43–45,49] and on strains in 8 studies.[14,24,25,37,41,43,44,49] The injury rate for both sexes was reported for concussion in 9 studies,[14,24,25,37,40,41,43,44,49] the ACL rate in 3 studies,[13,14,42] ankle sprains in 2 studies,[37,43] and Achilles tendon injuries in 2 studies.[13,41] Hamstring injuries were not included in the meta-analysis because they were reported in only 1 study.[37] The pooled IRR indicates a significantly higher rate of ACL injuries (IRR = 2.15, 95%CI: 1.27−3.62; $I^2 = 0\%$) in female compared to male athletes (Table 2). No significant differences between sexes were identified for the other injury types. In the meta-regression analyses (Table 2) for sprains and concussions, no significant moderators for the IRR between females and males were found. No volleyball studies were included in the meta-regression analysis.

4. Discussion

This meta-analysis compared the injury incidence between female and male players in 6 team sports. Only studies with injury data for both sexes were included, and their IRRs were used for data pooling. All of the 20 studies finally included had moderate to high methodological quality. The results emphasize the presence of sex-specific differences and, importantly, the direction of these effects differs depending on injury characteristics. Male team-sport players have a higher rate of overall, upper extremity, hip/groin, thigh, and foot injuries

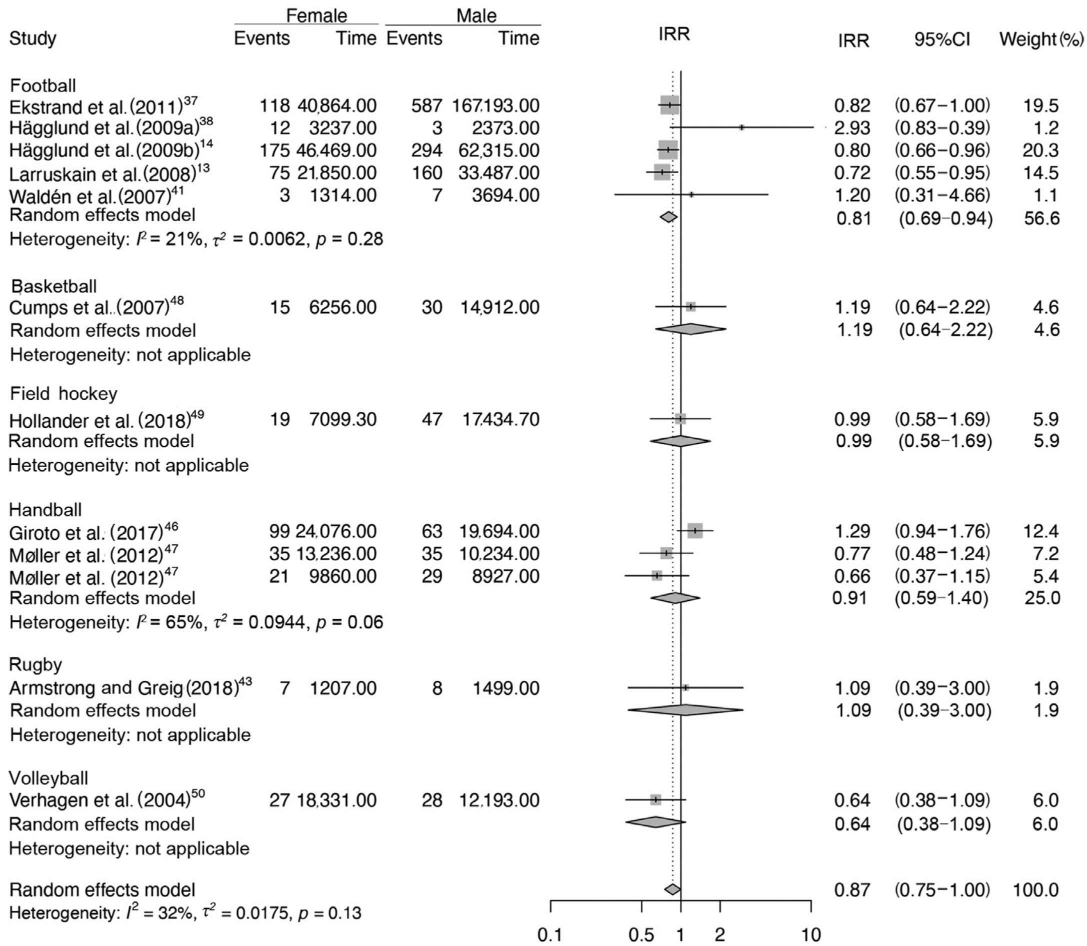

Fig. 4. Forest plot with the pooled incidence rate ratios (IRRs) and 95% confidence intervals (95%CIs; lower limit to upper limit) of the female *vs*. male comparisons for training injuries.

compared to female players. There is also a trend showing more match and training injuries in males compared to females, although the IRR was not significant. Female athletes showed a 2.15 times higher rate of ACL injury than males, but no significant sex differences were found for sprains, strains, concussions, ankle sprains, or Achilles tendon injuries. To date, almost no meta-analytic data exist for sex-specific differences of sports injuries. For running injuries, a meta-regression

Table 1
Pooled IRR, 95%CI, I^2, and meta-regression *p* values for specific body locations.

	Head	Upper extremity	Trunk	Hip/Groin	Thigh	Knee	Ankle	Foot
Study (*n*)	11	11	11	11	10	11	11	10
Meta-analysis								
IRR	1.00	0.75	1.02	0.60	0.69	0.95	0.91	0.64
95%CI	0.81−1.22	0.57−0.99	0.65−1.61	0.41−0.88	0.58−0.81	0.77−1.16	0.76−1.07	0.46−0.88
I^2 (%)	5.4	30.3	52.6	41.5	0	20.4	0	0
Meta-regression (*p*)								
Tournament *vs.* season	0.863	0.369	0.681	0.980	0.672	0.374	0.907	0.458
Injury definition	0.082	0.577	0.276	0.468	0.723	0.817	0.714	0.266
Age level	0.138	0.249	0.834	0.029	0.860	0.637	0.676	0.172
Quality score	0.885	0.706	0.182	0.338	0.178	0.336	0.744	0.625
Type of sport								
F *vs.* B	0.116	0.860	0.117	0.915	0.807	0.243	0.626	0.301
F *vs.* FH	0.248	0.041	0.527	0.730	0.332	0.282	0.662	0.101
F *vs.* H	0.236	0.125	0.120	0.635	0.655	0.862	0.617	0.314
F *vs.* R	0.563	0.360	0.008	0.001	0.972	0.777	0.471	0.488

Note: An IRR below 1 indicates a higher injury incidence in males.
Abbreviations: 95%CI = 95% confidence interval; B = basketball; F = football; FH = field hockey; H = handball; IRR = incidence rate ratio; R = rugby.

Table 2
IRR, 95%CI, I^2, and meta-regression *p* values for specific injury types.

	Sprain	Strain	Concussion	ACL injury	Ankle sprain	Achilles tendon injury
Studies (*n*)	10	9	10	3	2	2
Meta-analysis						
IRR	0.90	0.88	1.23	2.15	1.00	1.07
95%CI	0.78−1.05	0.65−1.18	0.84−1.81	1.27−3.62	0.71−1.39	0.46−2.50
I^2 (%)	0	51.5	17.0	0	0	40.1
Meta-regression (*p*)						
Tournament *vs.* season	0.487	—	0.375	—	—	—
Injury definition	0.952	—	0.226	—	—	—
Age level	0.844	—	0.531	—	—	—
Quality score	0.911	—	0.583	—	—	—
Type of sport		—		—	—	—
F *vs.* B	0.470		0.815			
F *vs.* FH	0.707		0.191			
F *vs.* H	0.730		0.573			
F *vs.* R	0.915					

Notes: An IRR below 1 indicates a higher injury incidence in males. No meta-regression was performed if fewer than 10 studies were available.
Abbreviations: 95%CI = 95% confidence interval; ACL = anterior cruciate ligament; B = basketball; F = football; FH = field hockey; H = handball; IRR = incidence rate ratio; R = rugby.

analysis[10] showed significantly more bone-stress injuries in females, whereas male runners were at higher risk for Achilles tendinopathies. This emphasizes our findings that suggest a different distribution of specific injury types and locations between sexes. However, contrary to Hollander et al.,[10] we also found significant differences between females and males in other injury categories.

4.1. Overall, match, and training injuries

The results show a significantly higher incidence of total injuries in male than in female players. Although there was a tendency toward higher rates in male players for match and training injuries, the rate ratio did not reach statistical significance. Not all included studies reported data on overall, match, and training injuries, which may have contributed to the different findings. Sixteen studies reported match injuries, but only 10 studies were available for training and overall injuries. Potential reasons for the higher overall injury rate in male team-sport players include multiple modifiable and nonmodifiable risk factors.[51,52] One explanation could be a difference in risk-taking behavior between sexes. In adolescent sports, female athletes have shown higher levels of perceived risk but lower levels of actual risk than male athletes.[51] In particular, the perceived risk (but not the actual risk) seems to be negatively associated with an increased rate of injury in sports.[51,53] Another possible explanation could be different loads in match/training or a different sport-specific performance of female and male players. For example, male football players were reported to cover more distance at higher speed thresholds than female players during a match.[52]

When taking a look at the sex-related rate ratio of the specific sports, the greater overall injury rate in male players compared to female players was confirmed for football and handball but not for the other team sports. However, because of the limited number of included studies, the data presented in the nonfootball sports should be viewed with caution.[32,54] For basketball, volleyball, and field hockey, only 2 or fewer studies were available, indicating a limited generalizability of the injury rate ratios. Data of single epidemiological studies depend heavily on the surveillance methods and/or circumstances and are of limited comparability. The methodological heterogeneity in injury surveillance studies and low comparability of data have been critically discussed elsewhere.[1,12]

4.2. Injury types and diagnoses

The significantly higher ACL injury rate in female players supports previous findings.[9] Possible explanations are greater neuromuscular-control deficits in females; an imbalance of muscle agonists, antagonists, and/or synergists; proprioceptive deficits;[55] or hormonal status.[56,57]

We found no significant differences between sexes for concussion rates. This is different from other studies and reviews that have reported a higher rate in females.[8,58] This may be explained by our restrictive study-selection criteria and the inclusion of only high-level team-sport athletes. The concussion risk seems to depend on sport-specific situations, such as tackling in male professional rugby,[59] and is associated with poor sleep quality and insomnia.[60] No plausible explanation exists for potential sex-specific differences.[61] However, it should be noted that greater concussion-reporting intentions in female athletes than in male athletes could influence study findings.[62]

The absence of sex differences in ankle sprains is in agreement with the literature review articles of Beynnon et al.[63] and Delahunt and Remus;[64] yet it contradicts the findings of the systematic review and meta-analysis done by Doherty et al.,[7] who showed that pooled incidence rates were twice as high in females as in males. These meta-analyses (ours and that of Doherty et al.[7]), however, are hard to compare due to the different study-inclusion criteria. Doherty et al.[7] included all available ankle-sprain studies, without a clear focus on a specific (sports) population. In our meta-analysis, only 2 studies with ankle sprain incidence rates[37,43]—in football and rugby players, specifically—met the narrow inclusion criteria.

4.3. Moderators of sex differences in injury rates

The type of sport, injury definition, age level, competition (tournament *vs.* season), and methodological quality score were considered to be potential moderators of sex differences in injury rates in our meta-regression analysis. The results show that the type of team sport significantly influences the rate ratio of overall, upper-extremity, trunk, and hip/groin injuries. For example, in contrast to the pooled data, Cumps et al.[48] showed a far higher overall injury incidence rate in female than in male basketball players. Furthermore, the sex differences were not present in the studies of rugby players, whereas the majority of other studies included football players and supported the higher injury rate in male athletes. Although some team sports were clearly under-represented in this meta-analysis, the results indicate that sex should not be considered a general risk factor[65] for overall sports injuries but should be viewed in interaction with the type of sport. Nonetheless, more surveillance studies are needed in sports other than football and rugby in order to strengthen the evidence.

The age level played no role in sex differences in most of the injury outcomes except for hip/groin injuries. Only 2 rugby studies[43,44] of collegiate athletes contributed to the differences in the sex-specific rate ratio for hip/groin injuries, so more research is needed in order to confirm or refute this finding. The training injury rate was significantly moderated by the injury definition, with more time-loss injuries in males and more physical complaints in females. One possible reason may be found in different reporting intentions. Female players seem to be more motivated to report minor (no time-loss) injuries than males.[62] Another explanation for the reported number of time-loss injuries could be the influence of the higher total training exposure for males compared to females. However, more studies are needed in order to strengthen these assumptions.

The observed sex-specific distribution of injuries in all analyzed categories did not differ between tournaments *vs.* seasons, nor were they influenced by the methodological quality of the studies.

4.4. Limitations

Although the narrow inclusion criteria (e.g., the inclusion of studies involving both sexes) helped to reduce the risk of bias, it produces a certain limitation at the same time. Numerous surveillance studies of various team sports that had large study samples and comprehensive data had to be excluded because they examined males or females exclusively or did not report sufficient data. This reduced the data in our meta-analysis, thereby weakening the evidence base, especially in nonfootball team sports. Some comparisons had only a single study for 1 team sport. This problem was addressed by displaying all-team-sports IRR alongside the sport-specific IRR. The low number of included studies also limits the findings on specific injury types, such as ankle sprains or Achilles tendon injuries. Moreover, only football studies were included in the meta-analysis for ACL injuries, which reduces the comparability of findings.

In almost half of the included studies, football dominated our meta-analysis and the reported findings. This may bias the conclusions for team sports in general and indicates the strong need for further studies with both female and male participants in nonfootball sports.

Another limitation is the heterogeneity of some estimates. Even though the influence of methodological specifications was reduced, and no strong moderator of risk ratio data other than type of sport was identified, the degree of inconsistency of the results across studies was substantial for overall ($I^2 = 73\%$) and match injuries ($I^2 = 80\%$). For the other injury outcomes, a nonrelevant or moderate heterogeneity was identified.[30,32]

Furthermore, although a number of moderators were tested for their potential influence on sex-specific differences, there might have been other influencing factors not considered in our meta-regression due to lack of information. For example, Ekstrand et al.[37] showed a different injury rate between female and male football players on different playing surfaces.

It should also be noted that the proportion of match to total exposure hours was slightly higher for females than males (27% *vs.* 23%), which may have influenced the overall injury incidence. Other limitations include the use of a nonvalidated scale for the methodological quality assessment. However, most of the categories were adopted from the standardized rating scales[8,27,28] and adapted for use in epidemiological injury studies.

5. Conclusion

The IRRs of our meta-analysis provide evidence for sex-specific differences in injury rates in team sports. Male players show higher rates for overall, upper extremity, hip/groin, thigh, and foot injuries compared to female players, whereas females have more ACL injuries. The overall, upper extremity, trunk, and hip/groin injury IRRs between sexes are moderated by type of team sport, indicating that sex should not be considered a general risk factor but be viewed in interaction with the specific sport. No or minor influence on the rate ratio was found for the age level, injury definition, or type of competition (tournament *vs.* season). Further epidemiological studies including both sexes in team sports other than football are needed in order to strengthen the evidence. Future research should also focus on sex-specific differences in other age groups (e.g., high school players), different playing level (e.g., recreational or military populations), and individual sports.

Authors' contributions

AZ did the study conception and design, data collection, statistics, and writing; KH, AJ, and SS participated in study conception and design and writing; ALR did the study conception and design, data collection, and writing; FN and DP helped with the data collection and writing; AG and JH did the statistics and writing. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jshs.2021.04.003.

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