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## TITLE PAGE

**Title:** Epidemiology of injuries in professional football: A systematic review and meta-analysis

**Running head:** Epidemiology of football injuries

**Authors:** López-Valenciano A<sup>1</sup>; Ruiz-Pérez I<sup>1</sup>, García-Gómez A<sup>2</sup>; Vera-García FJ<sup>1</sup>, De Ste Croix M<sup>3</sup>, Myer G<sup>5</sup>, Ayala F<sup>3,5</sup>

<sup>1</sup>: Sports Research Centre, Miguel Hernández University of Elche, (Alicante, Spain).

<sup>2</sup>: Operative Research Centre, Miguel Hernández University of Elche, (Alicante, Spain).

<sup>3</sup>: School of Physical Education, Faculty of Sport, Health and Social Care, University of Gloucestershire, (Gloucester, United Kingdom).

<sup>4</sup>: Division of Sports Medicine, Cincinnati Children's Hospital Medical Center, (Cincinnati, USA).

<sup>5</sup>: Postdoctoral fellow from Seneca Foundation.

**Corresponding Author.** Francisco Ayala. Sports Research Centre, Miguel Hernández University of Elche. Avda. de la Universidad s/n. 03202 Elche, Alicante, Spain. Email address: Franciscoayalarodriguez@gmail.com

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**Title:** Epidemiology of injuries in professional football: A systematic review and meta-analysis

### **ABSTRACT**

**Objective:** We performed a systematic review and meta-analysis of epidemiological data of injuries in professional male football.

**Method:** Forty-four studies have reported the incidence of injuries in football. Two reviewers independently extracted data and assessed trial quality using the STROBE statement and Newcastle Ottawa Scale. Studies were combined in a pooled analysis using a Poisson random effects regression model.

**Results:** The overall incidence of injuries in professional male football players was 8.1 injuries/1000 hours of exposure. Match injury incidence (36 injuries/1000 hours of exposure) was almost ten times higher than training injury incidence rate (3.7 injuries/1000 hours of exposure). Lower extremity injuries had the highest incidence rates (6.8 injuries/1000 hours of exposure). The most common type of injury was muscle/tendon (4.6 injuries/1000 hours of exposure), which were frequently associated with traumatic incidents. Minor injuries (1-3 days of time loss) were the most common. The incidence rate of injuries in the top 5 European professional leagues was not different to that of the professional leagues in other countries (6.8 vs. 7.6 injuries/1000 hours of exposure, respectively).

**Conclusions:** Professional male football players have a substantial risk of sustaining injuries, especially during matches.

## INTRODUCTION

A professional football team with a 25 player-squad typically suffers about 50 injuries that cause time-loss from play each season, which equates to two injuries per player per season.<sup>2</sup>

Player match availability has a strong correlation ( $r > 0.85$ ) with team success (i.e. ranking position, games won, goals scored, total points).<sup>4 5</sup> Injuries are also a financial burden to football clubs--the average cost of a player in a professional top team being injured for 1 month is calculated to be around €500.000.<sup>6</sup>

Therefore, it is important to quantify the injury incidence in professional football.<sup>7 8</sup> There have been a number of prospective cohort studies investigating injuries sustained by football players since the end of the 1970s,<sup>2</sup> and the publication of a consensus statement on injury definitions and data collection procedures in 2006<sup>9</sup> has improved the consistency and quality of research within the field. In the latter two decades (1998-2018) several epidemiological studies have been published describing injury patterns over one<sup>10-13</sup> or numerous<sup>2 14-16</sup> seasons and during tournaments with national teams<sup>17-20</sup> in male football players. However, despite the large number of studies reporting the incidence and severity of football-related injuries,<sup>2 10 21-23</sup> no studies have combined and meta-analysed such epidemiological data.<sup>24</sup> Identifying the most common and severe injuries as well as where (anatomical location) and when (matches or training sessions) they usually occur would lead coaches, physical trainers, physiotherapists and physicians to prioritise the application of specific measures to prevent or reduce the risk of sustaining such injuries.

Therefore, we conducted a systematic review and meta-analysis quantifying the incidence of injuries in professional male football. Our secondary purpose was to carry out sub-analyses to determine the overall effects regarding location of injuries, type of injuries, severity of injuries, overuse and traumatic injuries, new and recurrent injuries, level of play and national leagues (clubs) and International tournaments (national teams).

## METHOD

To conduct this study, guidelines for reporting meta-analysis of observational studies in epidemiology (PRISMA guidelines) were followed.<sup>25</sup> The PRISMA checklist is presented in appendix 1.

## **Study selection**

To be included in the meta-analysis, the studies had to fulfil the following criteria: 1) injury must be defined in terms of time loss (i.e. injury that results in a player being unable to take a full part in future football training or match play);<sup>9 26</sup> 2) participants had to be professional male football players (i.e. players who belong to teams engaged in professional national football leagues);<sup>21</sup> 3) the study had to be a full text article published in a peer-reviewed journal before March 2018; 4) eligible studies must report either incidence rate or prevalence among the surveyed players or provide sufficient data from which these figures could be calculated through standardised equations. Studies using injury definitions other than time loss were excluded. Literature reviews, abstracts, editorial commentaries and letters to the editor were also excluded. Finally, some authors were contacted to provide missing data or to clarify if data were duplicated in other publications. Incomplete data, or data from an already included study, were excluded.

## **Search strategy**

Potential studies were identified by using a systematic search process. Firstly, the following bibliographical databases were searched: PubMed, Scopus, EMBASE, AMED, Google Scholar and the Cochrane Library with the following search terms included in Boolean search strategies:

(soccer [tiab] OR soccer [mesh] OR football [tiab] OR football [mesh]) AND (injury [tiab] OR injury [mesh] OR injuries [tiab] OR injuries [mesh]) AND (professional [tiab] OR professional [mesh] OR elite [tiab] OR elite [mesh]). The search was limited to publication dates (to 28/02/2018). Secondly, several specialized electronic journals were also searched, including: British Journal of Sports Medicine, American Journal of Sports Medicine, British Medical Journal, Scandinavian Journal of Medicine & Science in Sports, European Journal of Sports Sciences. Finally, the reference lists of the studies recovered were hand-searched to identify potentially eligible studies not captured by the electronic searches.

Two reviewers independently (A.L. and I.R.): a) screened the title, abstract and reference list of each study to locate potentially relevant studies, and once hardcopies of the screened documents were obtained; b) reviewed them in detail to identify articles that met the selection criteria. A third external reviewer (F.A.) was consulted to resolve discrepancies about the selection process.

## **Data extraction**

With the aim of guaranteeing the maximum possible objectivity, a codebook was produced that specified the standards followed in coding each of the characteristics of the studies. The codebook can be obtained from the corresponding author upon request. The moderator variables of the eligible studies were coded and grouped into three categories: 1) general study descriptors (e.g.: authors, year of publication, and study design); 2) description of the study population (e.g.: sample size, age and level of play); and 3) epidemiological data (e.g.: injury and exposure data, distribution of injuries by anatomic location, type of injury, injury severity). If applicable, the authors of included studies were contacted to provide clarifications or access to raw data. Operational definitions used in the meta-analysis are shown in appendix 2. Appendix 3 also displays the moderator variables coded separately by category.

The purpose of the current meta-analysis was to determine the overall effects of: 1) football-related injury incidence (overall vs. training vs. match injuries rates); 2) location of injuries (lower extremity vs. trunk vs. upper extremity vs. head and neck); 3) type of injuries (fractures and bone stress vs. joint [non-bone] and ligament vs. muscle and tendon vs. contusions vs. laceration and skin lesion vs. central/peripheral nervous system vs. undefined/other); 4) severity of injuries (slight/minimal [1-3 days] vs. minor/mild [4-7 days] vs. moderate [8-28 days] vs. major/severe [ $>28$  days]); 5) mechanism of injury (overuse vs. traumatic injuries); 6) new vs. recurrent injuries; 7) level of play (top-5 European professional leagues vs. other professional leagues), and 8) national leagues vs. International tournaments [tournaments with national teams]).

## **Quality assessment**

The reporting quality of included studies was assessed using an adapted version of the “Strengthening the Reporting of Observational Studies in Epidemiology” (STROBE) statement by Vom Elm et al.<sup>27</sup>. Thus, all included studies were rated on 11 specific criteria which were derived from items 5, 6, 7, 8, 9, 12, 14 and 15 of the original checklist. This 11-item checklist provides guidance on the reporting of observational studies to facilitate critical appraisal and interpretation of results.

Furthermore, to assess risk of bias of external validity quality, an adapted version of the Newcastle Ottawa Scale (NOS) for cohort studies was used. The original NOS is a quality assessment tool for cohort and case-control studies which contains eight items categorized into three domains (selection, comparability and exposure) and uses a star rating system to indicate the quality of a study (maximum of nine stars).<sup>28</sup> The instrument was modified for

the purpose of this review (the incidence of injuries) and the population of football players. 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 on the basis of the design or analysis) was excluded because it was linked to item 2. Two new items were added to the original scale (items 1 and 3). Therefore, the criteria adopted to assess risk of bias were: (1) description or type of football players; (2) definition of injury; (3) representativeness of the exposed cohort; (4) ascertainment of exposure; (5) demonstration that the outcome of interest was not present at the start of study; (6) assessment of outcome; (7) whether follow-up was long enough for outcomes to occur; (8) 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 8 stars could be given to an article. The higher the number of stars given to an article the lower the risk of bias. Similarly, modified versions of this checklist have been used previously in systematic reviews investigating the epidemiology of injuries in other cohorts of athletes.<sup>29 30</sup> Appendix 4 displays a brief description of each item of the adapted version of the NOS tool used in this study.

The data extraction and quality assessment (including risk of bias of external validity) were conducted by two reviewers (A.L. and I.R.). To assess the inter-coder reliability of the coding process, these two reviewers (A.L. and I.R) coded 22 studies randomly (50%) (including quality assessment). For the quantitative moderator variables intra-class correlation coefficients (ICC<sub>3,1</sub>) were calculated, while for the qualitative moderator variables Cohen's kappa coefficients were applied. On average, the ICC was 0.89 (range: 0.78 - 1.0) and the kappa coefficient was 0.90 (range: 0.81 - 1.0), which can be considered highly satisfactory, as proposed by Orwin and Vevea<sup>31</sup>. Inconsistencies between the two coders were resolved by consensus, and when these were due to ambiguity in the coding book, this was corrected. As before, any disagreement was resolved by mutual consent in consultation with a third reviewer (F.A.).

### **Statistical analysis**

Injury incidence rates per 1000 hours of player exposures were extracted from the included studies. If injury incidence rates were not specifically reported, they were, if possible, calculated from the available raw data using the following formulas:

$$\text{Incidence} = 1000 \times (\sum \text{injuries} / \sum \text{exposure hours})$$

$$\text{Incidence} = \text{n}^\circ \text{ of injuries} / (\text{n}^\circ \text{ of matches} \times 11 \text{ players} \times \text{match duration}^*) \times 1000$$

\* Match duration, using the factor 1.5, based on standard 90 min match play. For example, a hypothetical study reporting that a football team comprising of 20 players sustained a total of 6 injuries within the season (38 matches), the application of the second formula would estimate an incidence of 9.6 injuries per 1000 hours of match exposure.

Data were modelled by a random effects Poisson regression model, as previously described.<sup>32</sup> The response variable was the number of observed injuries, offset by the log of the number of exposure hours. A random effects term was included to account for the correlation arising from using multiple rows of data from the same study. Factors of interest were included as random effects. A weighting factor used was: study exposure time [hours]/mean study exposure time [hours]. The possible influence of the following variables on the model was analysed independently through univariate and multivariate analyses: registration period; year of the study publication, age of the players, STROBE score, NOS stars and number of teams included in the study. Only those studies that rigorously and clearly followed the definitions of injury described by Fuller<sup>9</sup> were included in the sub-analyses.

Heterogeneity was evaluated using the  $I^2$  statistic, which represents the percentage of total variation across all studies due to between-study heterogeneity.<sup>33</sup> All statistical analyses were performed using the statistical software package R Version 2.4.1 (The R Foundation for Statistical Computing) and the “metafor” package.<sup>34</sup>

For injury incidence data, the overall estimated means for each random-effect factor were obtained from the model and then back-transformed to give incidence rates, along with 95% confidence intervals (CIs).

## RESULTS

### Descriptive characteristics of the studies

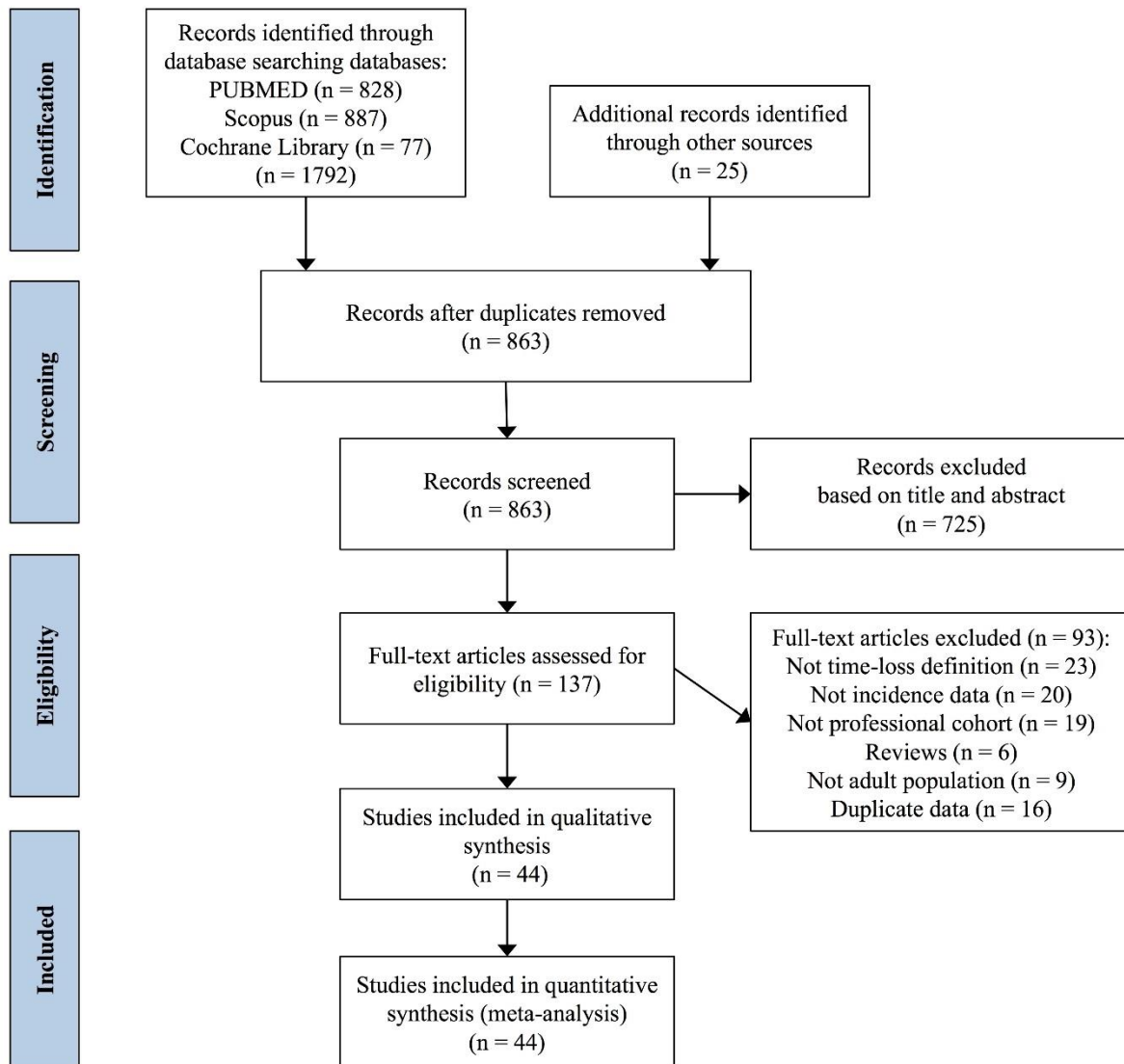
A total of 2013 references were identified with all search strategies, from which 537 were excluded in the first screening as duplicates (26.6 %). One thousand three hundred and eleven studies (65.1 %) were eliminated after reading the title and abstract. Another 23 studies did not report injury incidence rates or were focused on specific types of injuries (e.g.: ankle sprains, hamstrings muscle strains) (1.1%). Ninety-eight did not comply methodologically with the established criteria such as injury definition, participants observed (amateur players or children) and data duplication (4.7 %).

The search process identified 44 articles (resulting in 56 cohort groups as 7 studies had more than one group) that met the inclusion criteria.<sup>10-12 15 17-21 23 35-68</sup> Figure 1 shows the flow chart of the selection process of the studies. The studies were carried out between 1989 and 2018 and comprised players from both tournaments (world<sup>17 18 20 45 46 56 57</sup> and continental<sup>19 23 64</sup>



tournaments) and professional football leagues in many countries.<sup>44 48 51 54 59 68</sup> Appendix 5 provides a descriptive summary of the characteristics of the included studies.

Figure 1. Flow chart of the selection of studies for the meta-analysis.



With regards to the reporting quality of the studies, the mean score obtained with the STROBE quality scale was 7.7 (minimum: 3, maximum: 11). In general, more recent studies (published from 2007 to 2017) had more information reported (8.5, 95%CI = 7.9 to 8.8) than older (published before 2007) studies (6.3, 95%CI = 6.0 to 7.0). The detailed data are presented in appendix 6. Regarding NOS scale, the mean score obtained was 7.0 (minimum: 5, maximum: 8). The detailed data are presented in appendix 7.

## Findings-Meta Analyses

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

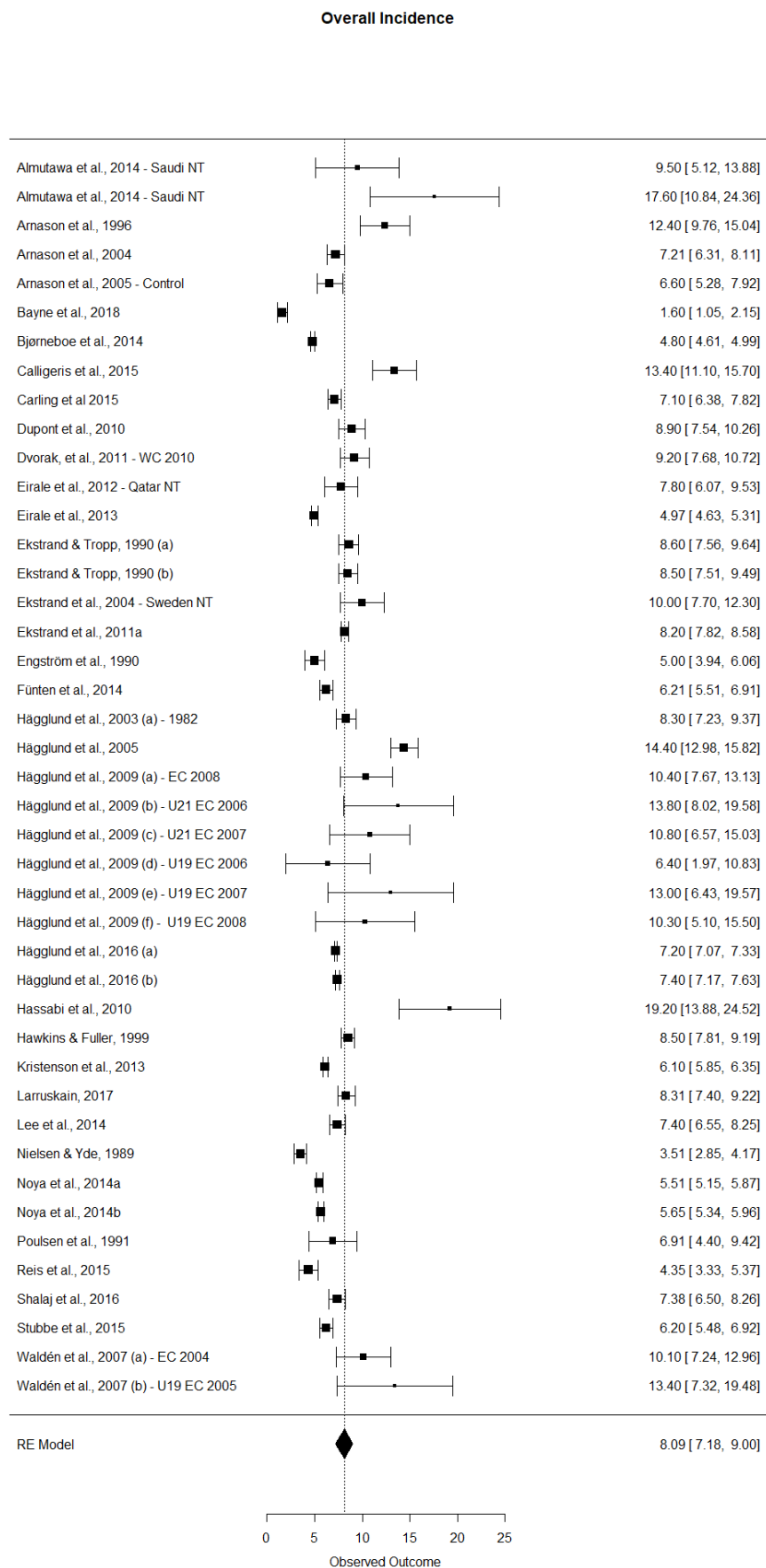
Neither registration period (i.e. the period of time /year when the data collection process was carried out), year of publication of the study, age, STROBE score, NOS stars and number of teams' variables had an impact on injury incidence rates and hence, the subsequent sub-analyses were not adjusted to these variables.

### Injury incidence: overall, training and match

Thirty-four studies (43 cohorts) reported overall injury incidence,<sup>10-12 15 19 21 23 35 37-41 43 44 46-51 53-55 58-63 65-68</sup> 30 studies (39 cohorts) reported training injury incidence,<sup>11 12 15 19 23 35 37-39 41 42 44 45 47-51 53 54 58-63 65-68</sup> and 40 studies (52 cohorts) reported match injury incidence<sup>11 12 15 17-20 23 35-39 41-54 56-68</sup> that could be combined in the meta-analysis. These studies comprised 29991 (overall), 12089 (training) and 14974 (match) injuries.

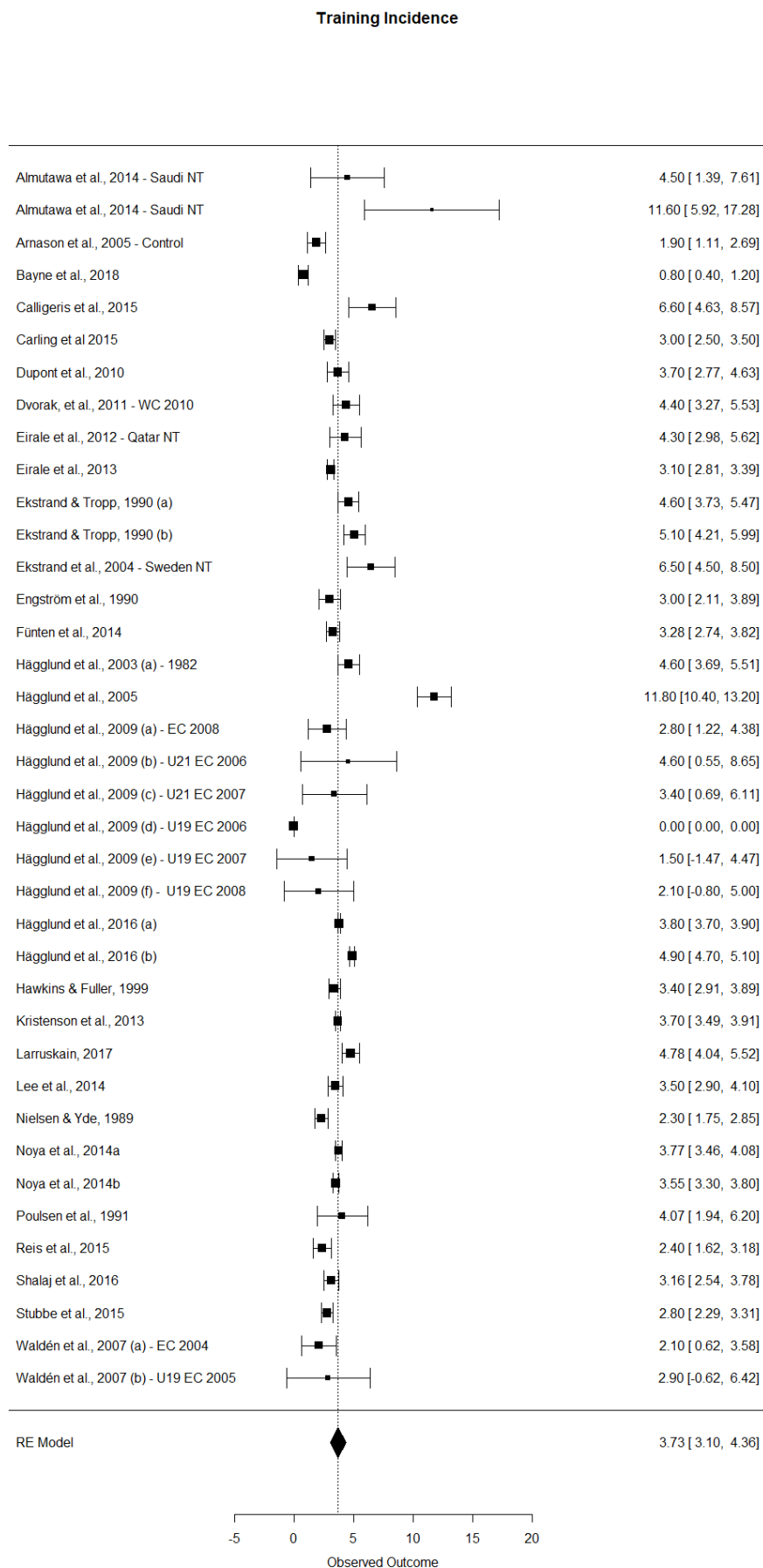
The random effect models for injury incidence showed an overall incidence of 8.1 injuries per 1000 hours of exposure (95%CI = 7.2 to 9.0,  $I^2 = 99.1\%$ ), a training incidence of 3.7 injuries per 1000 hours of training exposure (95%CI = 3.1 to 4.4,  $I^2 = 98\%$ ) and a match incidence of 36.0 injuries per 1000 hours of match exposure (95%CI = 31.3 to 40.8,  $I^2 = 98.9\%$ ). Figures 2-4 display a summary of the reported overall, training and match injury incidence rates of the analysed studies, respectively.

Figure 2. Overall injury incidence forest plot with 95% confidence intervals.



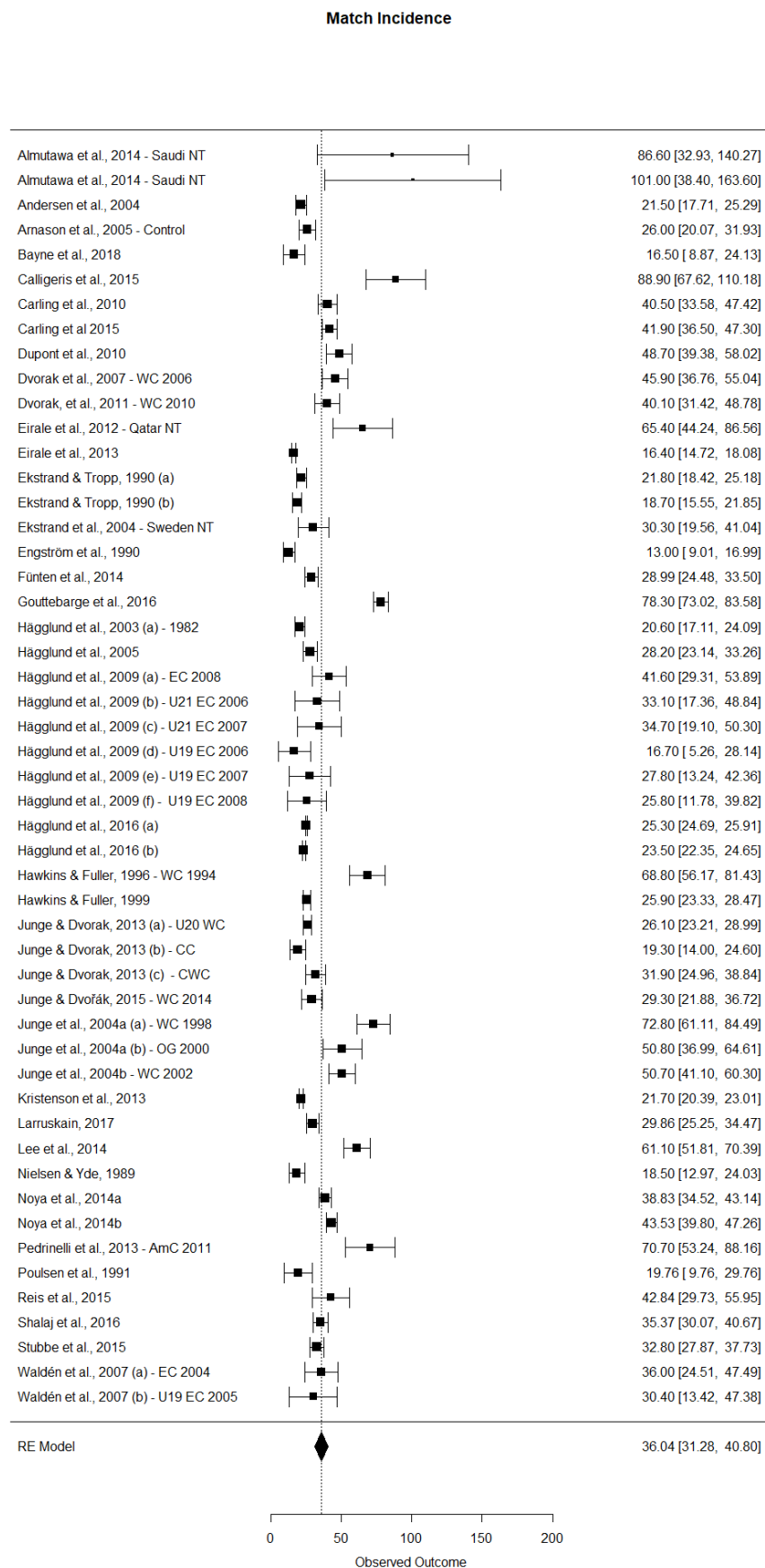
EC: Europe Tournament; NT: National team; U: Under; WC: World Tournament.

Figure 3. Training injury incidence forest plot with 95% confidence intervals.



EC: Europe Tournament; NT: National team; U: Under; WC: World Tournament.

Figure 4. Match injury incidence forest plot with 95% confidence intervals.



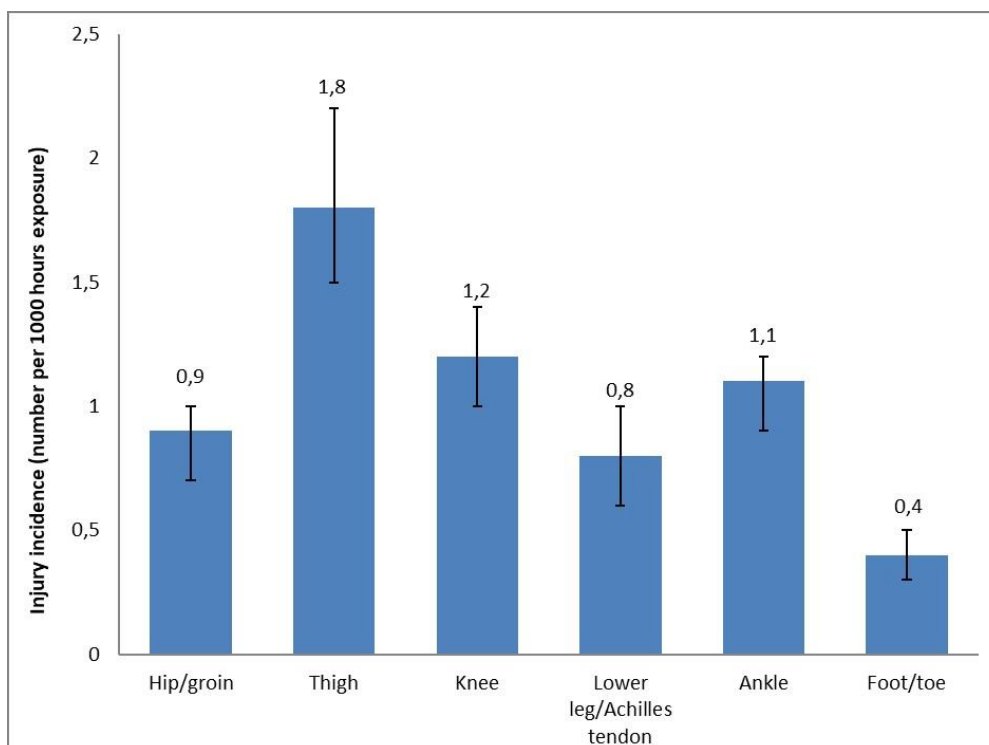
AmC: American Tournament; CC: Confederation Tournaments; CWC: Clubs World Tournaments; EC: Europe Tournament; NT: National team; OG: Olympic Games; U: Under; WC: World Tournament.

## Location of injury

Twenty-five studies (26 cohorts) reported injury location (i.e. lower extremity, trunk, upper extremity, head and neck) and lower extremities region categories (i.e. thigh, hip/groin, knee, lower leg/Achilles tendon, ankle, and foot/toe) according to Fuller et al.<sup>9</sup> which were pooled in the meta-analysis.<sup>2 10 15 19 21 37-40 42 44 45 47 48 50 51 53 55 59 60 62 63 65 67 68</sup> Lower extremity injuries had the highest incidence rates (6.8 per 1000 hours of exposure, 95%CI = 5.7 to 7.8,  $I^2 = 98.86$ ) compared to the other body regions. The trunk was the second most commonly injured region (0.4 per 1000 hours of exposure, 95%CI = 0.3 to 0.5,  $I^2 = 97.67$ ), upper extremity was the third most commonly injured region (0.3 per 1000 hours of exposure, 95%CI = 0.2 to 0.4,  $I^2 = 98.32$ ) and head and neck injuries had the lowest incidence rates (0.2 per 1000 hours of exposure, 95%CI = 0.1 to 0.2,  $I^2 = 96.3$ ).

Regarding lower extremity injuries, six anatomical regions were analysed. The mean incidence per 1000 player hours of exposure with 95% CIs were in descending order: thigh (1.8, 95%CI = 1.5 to 2.2,  $I^2 = 91.78$ ); knee (1.2, 95%CI = 1.0 to 1.4,  $I^2 = 91.86$ ); ankle (1.1, 95%CI = 0.9 to 1.2,  $I^2 = 92.58$ ); hip/groin (0.9, 95%CI = 0.7 to 1.0,  $I^2 = 95.32$ ); lower leg/Achilles tendon (0.8, 95%CI = 0.6 to 1.0,  $I^2 = 93.01$ ); and foot/toe (0.4, 95%CI = 0.3 to 0.5,  $I^2 = 91.4$ ) (Figure 5).

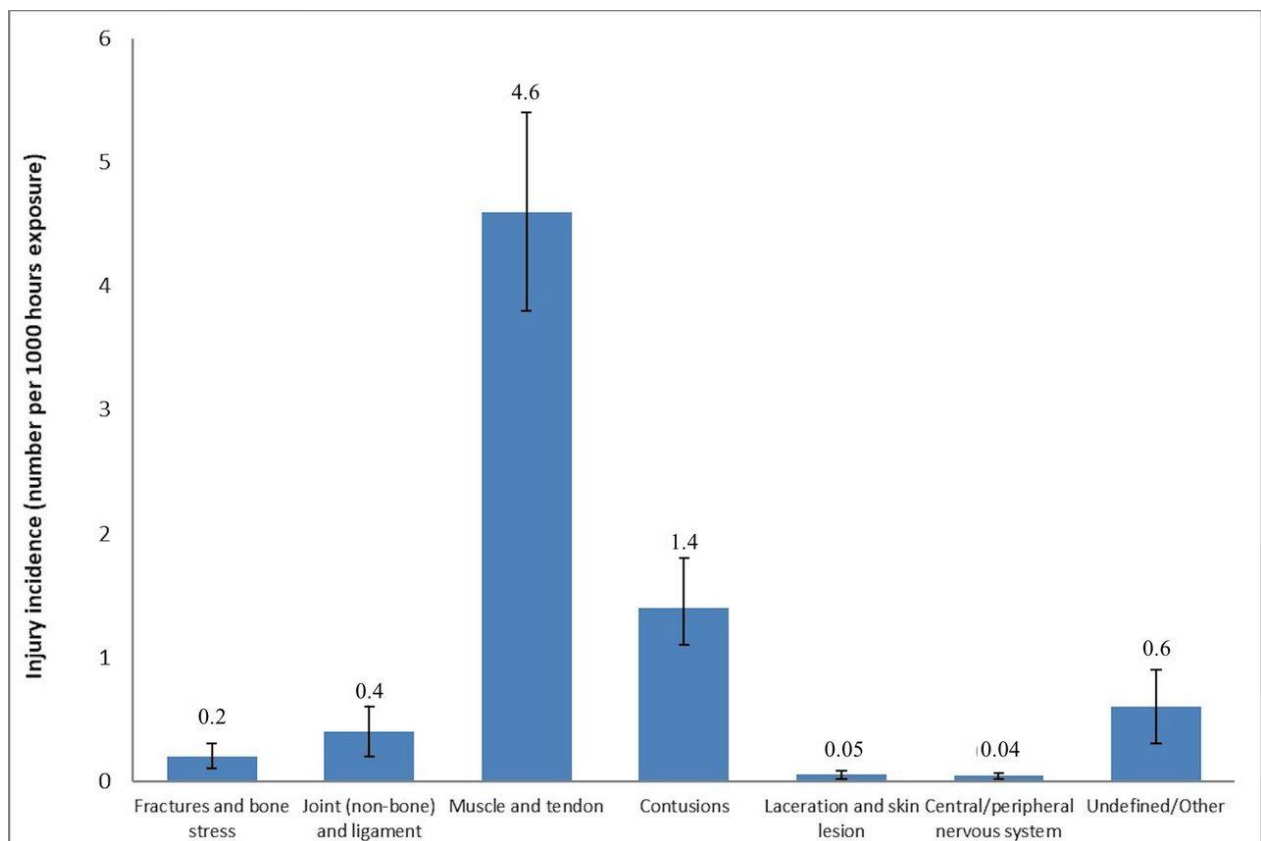
Figure 5. Injury incidence rates (with 95% confidence intervals) by location of lower extremity injuries.



## Type of injury

Twenty-four studies (26 cohorts) were included in the pooled analysis.<sup>2 10 15 19 21 37 39-41 45 47 48 50 51 53 55 59 60 62 63 65-68</sup> The mean incidence is presented per 1000 hours of exposure with 95% CIs. The most common type of injury grouping was muscle/tendon (4.6, 95%CI = 3.8 to 5.4,  $I^2 = 98.71$ ), followed by contusions (1.4, 95%CI = 1.1 to 1.8,  $I^2 = 97.65$ ), undefined/other injuries (0.6, 95%CI = 0.3 to 0.9,  $I^2 = 97.92$ ), joint (non-bone) and ligament (0.4, 95%CI = 0.2 to 0.6,  $I^2 = 98.02$ ), fracture and bone stress (0.2, 95%CI = 0.1 to 0.3,  $I^2 = 98.16$ ), laceration and skin lesions (0.05, 95%CI = 0.02 to 0.08,  $I^2 = 98.52$ ) and the least common injury type grouping was central/peripheral nervous system injuries (0.04, 95%CI = 0.02 to 0.06;  $I^2 = 98.19$ ) (Figure 6).

Figure 6. Injury incidence (with 95% confidence intervals) by type of injury.



## Severity of injury

Concerning severity of injuries, 21 studies (28 cohorts) were included in the pooled analysis.<sup>2 12 15 19 23 35 39 42 44 45 47 48 51 53 59 60 62 63 66-68</sup> Minimal injuries (3.1 per 1000 hours of exposure, 95%CI = 2.4 to 3.9,  $I^2 = 98.75$ ) were the most usual injuries, followed by moderate (2.0 per 1000 hours of exposure, 95%CI = 1.7 to 2.4,  $I^2 = 92.58$ ), minor (1.7 per 1000 hours of

exposure, 95%CI = 1.4 to 2.1,  $I^2 = 94.73$ ) and severe (0.8 per 1000 hours of exposure, 95%CI = 0.6 to 1.0,  $I^2 = 91.63$ ) injuries (Appendix 8).

### **Mechanism of injury**

Twenty studies (26 cohorts) were involved in the meta-analysis to compare overuse injuries versus traumatic injuries.<sup>10 11 19 21 23 37 40 41 44 47 48 51 53 59 60 62 63 66-68</sup> The incidence in traumatic injuries (5.9, 95%CI = 4.7 to 7.1,  $I^2 = 99.32$ ) was higher than in overuse injuries (2.4, 95%CI = 1.9 to 3.0,  $I^2 = 98.31$ ).

### **New vs. recurrent injuries**

Fifteen studies (21 cohorts) were included in an analysis which compared the incidence of new versus recurrent injuries.<sup>15 23 37 41 44 45 47 48 53 54 59 60 63 66 68</sup> The incidence rate of new injuries (7.0 per 1000 hours of exposure, 95%CI = 6.0 to 8.1,  $I^2 = 98.84$ ) was higher than recurrent injuries incidence rate (1.3 per 1000 hours of exposure, 95%CI = 0.8 to 1.8,  $I^2 = 98.53$ ).

### **Level of play**

For level of play, 32 studies were divided into two groups: a) top-5 European professional leagues as ranked by UEFA in 2018 (<https://www.uefa.com/memberassociations/uefarankings/index.html>) (La Liga [Spain], Premier League [England], Serie A [Italy], Bundesliga [Germany] and Ligue1 [France]) and b) other professional leagues in the world (outside the top-5 European professional leagues). Seven studies were performed in clubs belonging to the top-5 European professional leagues and reported overall<sup>15 42 43 51 59 62 63</sup> training<sup>15 42 51 59 62 63</sup> and match<sup>15 42 43 51 59 62 63</sup> incidence rates respectively. Alternatively, 25 studies were conducted in the professional leagues outside of the top-5 European professional leagues, and also reported overall,<sup>10 12 21 37-41 48-50 53-55 58 60 61 65-68</sup> training,<sup>12 37-39 41 48-50 53 54 58 60 61 65-68</sup> and match,<sup>12 36-39 41 48-50 52-54 58 60 61 65-68</sup> incidence rates. Overall incidence rate in professional leagues was not significantly different than top-5 European leagues (7.6, 95%CI = 6.2 to 9.0 vs. 6.8, 95%CI = 5.8 to 7.9 respectively). The mean incidence rates in training and match were in descending order: top-5 European leagues match: 35.5 (30.0 to 40.9,  $I^2 = 90.23$ ), other professional leagues match: 31.9 (23.2 to 40.6,  $I^2 = 97.23$ ), other professional leagues training: 3.9 (2.9 to 5.0,  $I^2 = 98.01$ ), and top-5 European professional leagues training: 3.6 (3.2 to 4.0,  $I^2 = 91.23$ ).



## National leagues vs. International tournaments

For this comparison, 44 studies were divided into two groups: a) national leagues - studies in football clubs of professional leagues; and b) international tournaments - studies in national teams during international tournaments. Twenty-eight, 24, and 27 studies carried out in football clubs reported overall, <sup>10 12 15 21 37-42 44 48-51 53-55 58-63 65-68</sup> training, <sup>12 15 37-39 41 42 44 48-51 53 54 58-63 65-68</sup> and match <sup>12 15 36-39 41-44 48-54 58-63 65-68</sup> incidence rates. On the other hand, six, six and 13 studies in national teams reported overall, <sup>11 19 23 35 45 47</sup> training <sup>11 19 23 35 45 47</sup> and match <sup>11 17-20 23 35 45-47 57 64</sup> incidence rates. Incidence rate in international tournaments was higher than national leagues (9.8, 95% CI = 8.8 to 10.8 vs. 7.5, 95% CI = 6.5 to 8.4, for international tournaments and national leagues). In particular, the mean incidence rates in training and match were in descending order: international match: 41.1 (33.9 to 48.2,  $I^2 = 90.69$ ); national match: 32.3 (26.7 to 37.9,  $I^2 = 96.43$ ); national training: 3.8 (3.2 to 4.5,  $I^2 = 98.37$ ); and international training: 3.5 (2.2 to 4.7,  $I^2 = 91.71$ ).

## DISCUSSION

The purposes of this study were to perform a systematic review and meta-analysis quantifying the incidence of injuries in professional male football as well as to conduct sub-analyses to determine the overall effects regarding location of injuries, type of injuries, severity of injuries, overuse and traumatic injuries, new and recurrent injuries, level of play and national leagues (clubs) and International tournaments (national teams).

### Injury incidence: overall, training and match

This meta-analysis indicates that the incidence rate per 1000 hours of exposure for professional male football players (8.1 injuries per 1000 hours of exposure) is lower than the injury incidence rate provided for professional male rugby players (12.6 injuries per 1000 hours of exposure).<sup>69</sup> The incidence rates in the current meta-analysis are similar to injury incidence rates provided in individual studies for amateur football players (5.1-10.9 injuries per 1000 hours of exposure)<sup>70-72</sup>, college ice hockey players (9.1 injuries per 1000 hours of exposure)<sup>73</sup> and senior handball players (6.3 injuries per 1000 hours of exposure).<sup>74</sup> Fortunately, although injuries occur frequently in professional football players, the majority appear to be of minimal severity (1-3 days lost from sport play).

In line with most team sports (e.g.: basketball,<sup>75</sup> handball,<sup>74</sup> rugby<sup>69</sup>), match/game injury incidence in football was notably higher (almost ten times) than the injury rate obtained for training sessions. A number of studies have attributed these differences in injury incidence rates between match and training to several factors, including the higher physical demands on players during matches in comparison with training sessions, the number of contacts and

collisions during matches and fatigue generated during the course of the match.<sup>2 76 77</sup> Furthermore, the variability and uncertainty generated in the players when competing against rivals in a match compared to teammates in training may potentiate these differences. Although still under debate, it has been suggested that training session design (i.e. work-load, intensity, duration), when possible, should mimic match demands so that players are better prepared for what they face during matches.<sup>78</sup> Although the limited number of studies published did not permit us to describe the pattern of injury incidence during the course of a football match, the current evidence shows that the incidence rates of some injuries tend to increase toward the end of each half.<sup>2 16 18 46 76 79</sup> The finding of a higher incidence of injuries in the second part of each half in comparison with other match periods may indicate that fatigue is implicated in injury aetiology, however, factors contributing to this (e.g. hydration, nutrition, neuromuscular compromise and biomechanical alterations to technique) require further investigation.

### **Location of injury**

As expected, lower extremity injuries were by far the most frequent location for an injury with an incidence rate of 6.8 injuries per 1000 hours of exposure. The thigh was the most commonly injured anatomical region followed by the knee. Furthermore, the most common type of injury grouping was muscle/tendon injuries. Due to the lack of studies reporting incidence rates separately for different muscle groups (e.g.: gluteus, hamstrings, quadriceps, abductors, adductors, triceps surae), a sub-analysis aimed at identifying the most injured muscle group was not possible. However, previous epidemiological studies have consistently reported that hamstring muscles are the muscle group most frequently injured in professional football players.<sup>68 76 80</sup> As previous studies exploring the location and type of football-related injuries have only reported incidence rates and not the average number of days lost from football (time loss), it was not possible for us to calculate the injury burden (the cross-product of severity [consequences] and incidence [likelihood]) to build a risk matrix. The risk matrix would have helped to identify the importance of each type of football-related injury and may provide information to help prioritize injury prevention measures used in professional football environments. Recently, Bahr, et al.<sup>81</sup> built a risk matrix based on data from the UEFA Elite Club Injury Study and suggested that injury reduction in the areas of the hamstring, groin, knee and ankle are priorities for coaching, medical and fitness staff, while concussions represent less of a health burden. According to Ekstrand, et al.<sup>3</sup>, the measures designed to reduce the injury burden should not only address the traditionally proposed modifiable injury risk factors (e.g.: eccentric strength deficits,<sup>82-84</sup> poor flexibility,<sup>85 86</sup> altered muscle architecture,<sup>87 88</sup> player load and match frequency<sup>10 89</sup>) but also some new external factors

such as the stability of the club in terms of coaching, medical staff and management, players adherence and coach compliance to the injury prevention program.<sup>90</sup>

### **Overuse vs. traumatic injuries**

In this study most of the football-related injuries had a traumatic mechanism, with an incidence rate of 5.9 injuries per 1000 hours of exposure, twice that of the incidence reported in overuse injuries (2.4 injuries per 1000 hours of exposure). In particular, being tackled or colliding with an opponent (i.e. during a jump) appear to be the most common injury incidents, representing approximately 50% of all traumatic injuries, followed closely by the injury incidents caused during non-contact actions such as sprinting and cutting (30% of all cases of traumatic injuries).<sup>91</sup> As it has been documented for young players,<sup>92 93</sup> the application of football-specific neuromuscular training programmes with the aim of optimizing players' motor competency, joint stability and delaying the onset of fatigue might reduce the relative risk of injury due to acute overload of soft tissues.

### **New vs. recurrent injuries**

As expected, recurrent injuries incidence is lower than the new injuries rate (1.3 vs. 7.0 injuries per 1000 hours of exposure). However, the recurrent rate identified in the present study may be considered high. It has been recently shown that most recurrent injuries (mainly lower extremity muscle and tendon injuries) occur within 2 months after return to play.<sup>54</sup> This may reflect a premature return to train/play and incomplete or inadequate rehabilitation. The lack of evidence-based criteria for a safe return to train/play alongside the fact that team managers and coaches may be tempted to let injured players return to play important matches or to let them play with ongoing minor symptoms might be two reasons behind the high recurrent injuries incidence rates. Future studies should extend our current knowledge in relation to improving the decision-making process for a safe return to training/play by developing learning algorithms or artificial intelligence-based models that allow the identification of when a player is fully and effectively rehabilitated before returning to training/play.<sup>94</sup>

### **Level of play**

The results of this study also highlight that the incidence rates overall, during training and match play were similar between top-5 level European leagues and the rest of the professional leagues. These findings suggest that although there may be differences in the number and density (i.e. match congestion) of matches played across the season between teams engaged in top-5 level European leagues and teams from other professional leagues, that this does not lead to a greater injury incidence rate. These findings were unexpected due to the fact a number of teams engaged in top-5 level European leagues must face a higher recurrence of

exposure to periods of short (i.e.  $\leq 3$  days elapsed between consecutive match exposures) and long-term match congestion (i.e.  $>7.5$  hours of match play exposure within 30 days) across the season (due to organizational reasons of their national leagues and their simultaneous participation in other national [e.g.: FA Cup and Football League Cup in England] and European [i.e. UEFA Europa League and UEFA Champion League] tournaments) in comparison with their counterparts from other (e.g.: Scandinavian leagues), but not all, professional leagues<sup>95</sup> and hence, a priori we predicted a higher incidence of injuries. However, a recently published 14-years prospective study with 2672 male professional football players included and more than 130 000 match observations found no associations between total match injury rates and high short- and long-term match congestion periods<sup>96</sup> which is in line with the results in the current meta-analysis. A possible explanation for these similar match incidence rates between top-5 level European leagues and the rest of the professional leagues could be linked to player rotation policies carried out in top level teams (e.g., sporadic exposure over the season, players only competing in 1 out of 2 matches in cycles played in a short time frame,  $<75$  min exposure time) that might have diluted the real risk of injury.<sup>97</sup>

#### **National leagues vs. International tournaments**

Finally, the present meta-analysis has also shown that the incidence rate during international matches (41.1 injuries per 1000 hours of exposure) was higher than during national matches (32.3 injuries per 1000 hours of exposure). The higher density of matches played, the mental stress and anxiety generated in the players and the fact that international competitions are usually played during summer periods (at the end of a long season where accumulated fatigue may play a part and during hot and dry climate conditions) have been suggested as contributing factors for this increase in the number of injuries.<sup>95 98</sup>

#### **LIMITATIONS**

Like other meta-analysis conducted in sport medicine settings,<sup>69 99</sup> variations in injury and severity definitions associated with older studies resulted in heterogeneous estimates of the main meta-analysis. Only those studies that rigorously and clearly followed the definitions of injury described by Fuller<sup>9</sup> were included in the sub-analyses. Also when different epidemiological data were used (e.g.: hours of athlete exposure, total number of injuries, number of matches played) and therefore various methods of data collection, we applied standardised formulas to account for this discrepancy. Nevertheless, even when our inclusion criteria for sub-analysis and standardised formulas were applied the degree of inconsistency of the results across studies were still very high ( $I^2 > 90\%$ ). Consequently, variations in injury

definitions and lack of uniform data collection methods may not have been the unique sources of inconsistency in the results. Other potential sources of inconsistency may have been the differences existing among the national leagues in terms of climatic regions (cooler and warmer areas),<sup>39</sup> periods of fixed match congestion,<sup>43 44</sup> numbers of matches and in-season breaks<sup>51</sup> as well as the level of professionalism.<sup>54</sup> Additionally, the sample size of studies included was not sufficient to investigate interactive effects within factors (e.g. playing position by level of play) or whether injury rates are associated with a violation of the competition rules (a variable that has not been thoroughly explored). This could for example help to assess whether the protective equipment used by players (shin pads) reduces injury risk or if other equipment is needed for certain positions (e.g. a helmet for the goalkeeper to protect themselves against concussions). Furthermore, the lack of studies that reported the average number of days lost from football, caused by specific types of injuries, did not allow us to present data on injury burden. Another limitation that should be mentioned is that this study was not eligible for inclusion in the International Prospective Register of Systematic Reviews (PROSPERO) database because the systematic review had progressed beyond the point of completing data extraction when the official registration process was addressed. Consequently, it was not possible to make a comparison between the predictive outcomes and those finally published in order to analyse any discrepancy. In our analysis separate incidence rates reported in studies that covered multiple seasons or cups were considered as independent when multiple comparisons were conducted. In this instance the same player may have been counted more than once over the different seasons. However, for each separate incidence rate recorded, the same player was counted only one time. Unfortunately only one author corresponded when asked for additional information subsequently limiting the data we had access to.

## **CONCLUSIONS**

Professional male football players are exposed to a substantial risk of sustaining injuries, especially during matches. Although most injuries had a traumatic mechanism (injuries with sudden onset and known cause), fortunately most of them appear to be of minimal severity. As might be expected the lower extremity is more frequently injured, and the most common type of injury is muscle/tendon strain. Recurrent injuries were less frequent than new injuries, although re-injury rates have implications for return to train/play management. Future studies should focus on introducing and evaluating preventative measures that target the most common diagnoses, namely, muscle/tendon injuries highlighted in this meta-analysis, in order to reduce the number and severity of injuries within male professional football players.

### **What is already known?**

- Injuries are one of the biggest problems in modern football.
- Some types of injuries have increased in past few decades.
- Professional male football players are exposed to a substantial risk of sustaining injuries, especially during matches.

### **What are the new findings?**

- Match injury incidence is almost ten times higher than training injury incidence rate.
- Although most injuries have a traumatic mechanism, most appear to be of minimal severity.
- It is confirmed that the lower extremity is more frequently injured, and the most common types of injuries are muscle/tendon strains.
- Injury incidence rates between the top-5 level European leagues and the rest of the professional leagues overall, in training and match play are similar.

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### **Competing interest**

None declared

### **Contributors**

AL, IR and FA were responsible for the conception and design of the study. AL and IR were involved in data collection over the study periods. MD conducted the analyses together with the biostatistician (AG) and they were planned and checked with GM and FV. All authors contributed to the interpretation of findings and had full access to all data. FA wrote the first draft of the paper, which was critically revised by MD, GM and FV. The final manuscript was approved by all authors. FA is the study guarantor.

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## **APPENDICIES**

Appendix 1. PRISMA checklist.

Appendix 2. Injury definitions.

Appendix 3. Moderator variables coded.

Appendix 4. Description of the 8 criteria designed to assess risk of bias of external validity quality in the studies<sup>T</sup>. This instrument is an adapted version of the Newcastle Ottawa Scale (NOS) for cohort studies.

Appendix 5. Characteristics of the studies included in the meta-analysis.

Appendix 6. Analysis of the selected studies' methodological quality -STROBE.

Appendix 7. Risk of bias assessment of the studies (Newcastle-Ottawa scale).

Appendix 8. Injury incidence (with 95% confidence intervals) by severity of injury.