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THE PREVALENCE OF MUSCULOSKELETAL INJURIES AMONG TRIATHLETES: A SYSTEMATIC REVIEW WITH META-ANALYSIS

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Abstract

The aim of this systematic review was to estimate the general prevalence of musculoskeletal injuries in triathletes. The study protocol was registered in PROSPERO (CRD42020210540). This systematic review with meta-analysis included cross-sectional and cohort studies that investigated a 12-month prevalence of musculoskeletal injuries, regardless of injury type. Studies that analyzed only one body area of the triathlete were excluded. The databases searched were Embase, Medline, Scopus, SPORDiscus, Web of Science, Lilacs, SciELO and CINAHL. The methodological quality and level of certainty of the evidence were assessed using the JBI Critical Appraisal Tool and the GRADE approach, respectively. Prevalence analysis was performed using the random effect model. Begg-Mazumdar and Egger tests were applied to assess publication bias. Nine studies were included in this review, totaling 2096 participants (81,4% men). The overall prevalence of musculoskeletal injuries at 12 months was 54% (I^2=98.5%, 95%CI 36–71%). The body region with the highest prevalence of injuries was the foot and ankle, with 27% (I^2=92.7%, 95%CI 17-36%). The prevalence of musculoskeletal injury in women and men was similar. This systematic review provides important information for sports medicine specialists who make decisions about appropriate injury prevention measures.

Keywords: Triathlon; Triathlete; Injury; Prevalence; Systematic review.

INTRODUCTION

A triathlon is an endurance sport that involves swimming, cycling, and running. This multi-sport has become popular in many countries, with over 50,000 athletes competing worldwide each year. Triathlon competitions have different formats which include events such as: short- and long-distance triathlons, Sprint, Olympics, Half-ironman, and Ironman.

Triathlon athletes, commonly referred to as triathletes, train for about six months before competitions and remain active throughout the year due to training periodization (BERTOLA; SARTORI; CORRÊA; ZOTZ; GOMES, 2014; MANNINEN; KALLINEN, 1996). The high training load and excessive repetition of sports gestures predispose these athletes to musculoskeletal injuries, which can interfere with the quality of training and performance during competitions (BERTOLA; SARTORI; CORRÊA; ZOTZ; GOMES, 2014; JOHNSTON; CAHALAN; O'KEEFFE; O'SULLIVAN; COMYNS, 2018).

In a recent study, Minghelli et al. (2020) showed that 54.6% of triathlon athletes reported injuries within 12 months, of which 66.3% had one injury, 30.5% had two injuries, and 3.2%, had three injuries (MINGHELLI; JESUS; MARTINS; JESUS, 2020). Other studies investigated the occurrence of injuries, and the results are contradictory owing to the heterogeneity of information, such as athletes' experiences, training frequency, and follow-up period (BERTOLA; SARTORI; CORRÊA; ZOTZ; GOMES, 2014; MINGHELLI; JESUS; MARTINS; JESUS, 2020; VLECK; MILLET; ALVES, 2014; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014).

Injuries in athletes can decrease adherence to sports, negatively influence an active lifestyle, and generate healthcare costs (HESPANHOL JUNIOR; VAN MECHELEN; VERHAGEN, 2017). Another adverse repercussion of the injury is mental health, as approximately 12% of athletes have depressive symptoms after a musculoskeletal injury (LICHTENSTEIN; NIELSEN; GUDEX; HINZE; JØRGENSEN, 2018). Frustration and impatience also recur when trying to return to sports (TRACEY, 2003). Information on the occurrence of injuries is essential for planning of the season, devising preventive strategies, and ensuring athletes' participation in competitions. To the best of the authors' knowledge, there are no compiled data on this topic. Therefore, this systematic review aimed to investigate the prevalence of injuries in triathletes over 12 months and to verify the pattern of distribution of injuries in triathletes.

METHODS

A systematic review and meta-analysis were performed, following the recommendations of the Joanna Briggs Institute Reviewers' Manual (The Systematic Review of Prevalence and Incidence Data) (MUNN; MOOLA; LISY; RIITANO; TUFANARU, 2015) and the guidelines of the Meta-analysis of Observational Studies in Epidemiology (MOOSE) group (STROUP; BERLIN; MORTON; OLKIN; WILLIAMSON; RENNIE; MOHER; BECKER; SIPE; THACKER, 2000). The study was reported following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PAGE; MCKENZIE; BOSSUYT; BOUTRON; HOFFMANN; MULROW; SHAMSEER; TETZLAFF; AKL; BRENNAN; CHOU; GLANVILLE; GRIMSHAW; HRÓBJARTSSON; LALU; LI; LODER; MAYO-WILSON; MCDONALD; MCGUINNESS; STEWART; THOMAS; TRICCO; WELCH; WHITING; MOHER, 2021).

Eligibility criteria

Studies that investigated the overall prevalence of musculoskeletal injuries over 12 months in amateur, professional, or elite triathletes of both sexes aged ≥ 18 years were included. Studies were included regardless of the characteristics of the investigated injuries (e.g., overuse, fractures, acute, and chronic). Studies that analyzed only one body area of a triathlete were excluded. If the same sample was used in more than one study, the one with the largest sample size and more variables analyzed was chosen. To clarify information that was not explicit in the study, we contacted the authors by email. The titles and abstracts were initially analyzed.

Search strategy

Electronic searches were performed from the oldest record to the previous date (1 March 2022) of article submission. The following databases were used: Embase, Medline, Scopus, SPORDiscus, Web of Science, Lilacs, SciELO and CINAHL without date and language restrictions. In addition, a second review of the related literature was performed using the reference lists of all eligible studies. The search strategy used the following keywords: “prevalence,” “epidemiology,” “injury,” “triathlon” and “triathlete”. These keywords were also combined using Boolean operators and/or added to all descriptors. The complete search strategy for each database is provided in the **Supplementary Material 1**.

Selection of studies

Two researchers (MRM and TMDO) independently screened studies. Initially, duplicates were excluded, and after reading the titles and abstracts, potentially eligible studies were selected. After these steps, the full texts were read and those that met the eligibility criteria were included. Reasons for exclusion from this step were recorded. In cases of disagreement, a third independent reviewer (JEF) resolved possible disagreements.

Data extraction

Two independent reviewers (MRM and TMDO) extracted relevant data from the participants using a predefined data extraction form, and disagreements were resolved by a third reviewer (JEF). The following data were extracted: study design, number of participants, triathlon experience, age, competitive distance, injury definition, injury site, injury type (trauma or overuse), and injury prevalence. For injury prevalence, the percentage and absolute number of events (injuries) were extracted.

Risk of bias assessment

Two independent reviewers (MRM and TMDO) assessed the risk of bias for each included study using the Joanna Briggs Institute's Critical Appraisal Checklist for Prevalence Studies tool (MUNN; MOOLA; RIITANO; LISY, 2014). Each of the nine items evaluated received the judgment of “yes,” “no” and “not clear” based on the information provided in the study. Each item was scored as one point, so the maximum score that each study could receive was nine points. A third reviewer (JEF) resolved all potential disagreements.

Certainty of evidence (GRADE assessment)

The overall certainty of evidence on the prevalence findings was judged according to the four levels of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system (BALSHEM; HELFAND; SCHÜNEMANN; OXMAN; KUNZ; BROZEK; VIST; FALCK-YTTER; MEERPOHL; NORRIS; GUYATT, 2011). Two reviewers (MRM and TMDO) independently assessed the certainty of evidence on pooled overall prevalence data according to the GRADE system criteria. The quality of evidence was lowered by one point when one of the following criteria was present: 1a) risk of severe bias: studies that met only four of the items on the risk of bias scale; 1b) moderate risk: studies that met between five and seven of the items on the risk of bias scale; 1c) low risk: studies that met between eight and nine of the items on the risk of bias scale; 2) severe inconsistency: when I^2 was greater than 40%; 3) serious indirectness: when the collection of information about the injury had not been confirmed by a professional; 4) publication bias: when detected through the Egger test: 5) imprecision: it was considered high when the “optimal information size” did not reach the total of 400 participants in the analysis.

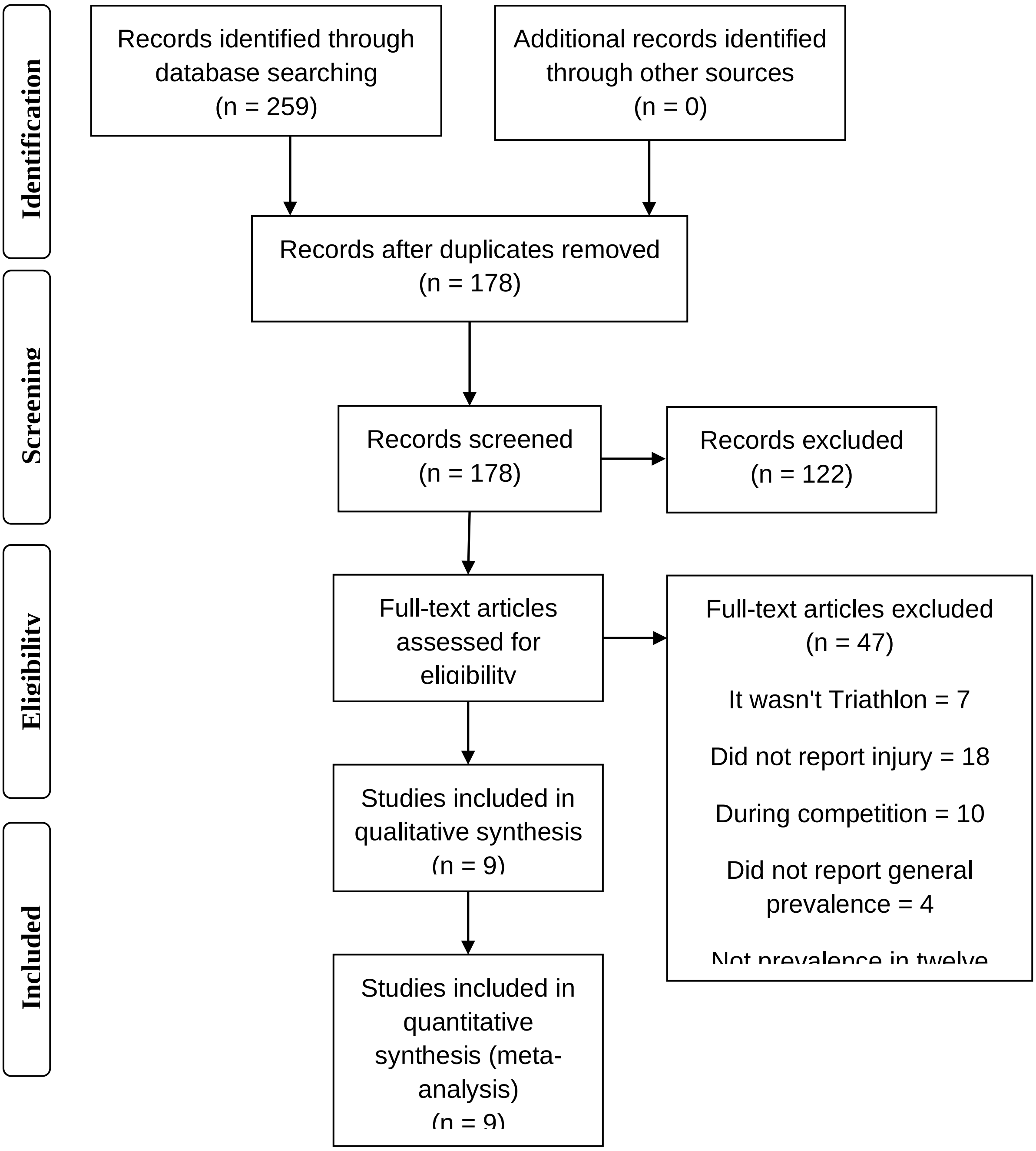
Statistical analysis

The data were initially analyzed using descriptive statistics. Prevalence estimates were expressed as percentages (proportion × 100), and their respective confidence intervals (CIs) were obtained from the total sample size and number of events (injuries) in each study. For all analyses, the estimated pooled effect was obtained using a random effects model. The I^2 test was used to assess the heterogeneity between studies. Heterogeneity was considered low if $I^2 < 50\%$ and high if $I^2 > 50\%$. Subgroup analyses were performed according to gender. Data were pooled only if the study duration was equal. A significance level of 5% was considered for all statistical tests. All statistical analyses were performed using the Stata software (version 16.0, StataCrop, College Station, Texas, USA).

RESULTS

Two hundred and fifty-nine studies were investigated. Of these, 56 were eligible for full-text analysis and 47 were excluded after reading the full text. Of the excluded articles, seven were unrelated to triathlon, 18 did not report injury data, ten occurred during competition, four did not report overall prevalence data, and eight did not report 12-month prevalence data. A flowchart of the study selection process is shown in **Figure 1.**

Figure 1. PRISMA search flow diagram



Description of included studies

Table 1 shows the nine studies included in this review. From a total of 2096 participants, 1708 were men and 388 were women. Two studies were cross-sectional (Minghelli et al., 2020; Shaw et al., 2004), six were retrospective (Collins et al., 1989; Galera et al., 2012; Galera et al., 2009; Korkia et al., 1994; Manninen & Kallinen, 1996; O'Toole et al., 1989) and one was prospective (Zwingenberger et al., 2014). These articles were published between 1989 and 2020. Four studies defined injury, and five studies did not present sufficient data to extract information on the prevalence of injury according to the sex of the participants. The prevalence of injury ranged from 14 to 92% between studies. The body regions with the highest prevalence of injuries were the foot and ankle (27%) followed by the knee (24%). The triathlon competitions evaluated in the included studies were Ironman, Half-Ironman, Olympics, and Sprint. The evaluated athletes varied in skill-level, ranging from amateurs to professionals **(Table 1)**.

Table 1. Descriptive analysis of the characteristic of included studies

				Participants	**Prevalence**		
Studies	**Definition of Injury**	**Race distance**	**Triathlon experience**	**n (F/M), age ± SD**	**Total (%)**	**F (%)**	**M (%)**
Collins et al, 1989	"Any musculoskeletal ailment that caused the athlete to stop training for at least 1 day, reduce mileage, take medicine, or seek medical care."	Not specified	Elite / Intermediate / Amateur	257 (60/197) 32 years	49	48	49
Galera et al., 2009	Not specified	Sprint / Half-Ironman	Amateur	43 (8/35) 35.6 ± 12.3 years	63	----	----
Galera et al., 2012	Not specified	Sprint / Half-Ironman	Amateur	309 (56/253) 38 years	51	46	29

Korkia et al., 1994	“An event which forced the athlete to stop the current training session or race and prevented a return to the session or rest the day after injury; or which caused any of the following: injury to the eye, teeth, or nerve; fracture; or concussion.”	Ironman / Half-Ironman / Olympics / Sprint	Elite / Intermediate / Amateur	155 (31/124) 33 ± 8.1	46	----	----
Minghelli et al, 2020	Not specified	Ironman / Half-Ironman / Olympics / Sprint	Professional / Amateur	174 (43/131) 36 ± 11 years	69	----	----
Manninen & Kallinen, 1996	Not specified	Ironman / Half-Ironman / Olympics / Sprint	Professional / Amateur	92 (22/70) 31.3 ± 7.4 years	72	36	41
O'toole et al, 1989	“The term injury was not defined for the triathletes but left to the judgment of each athlete.”	Ironman	Professional / Amateur	95 (20/75) 36 years	92	----	----

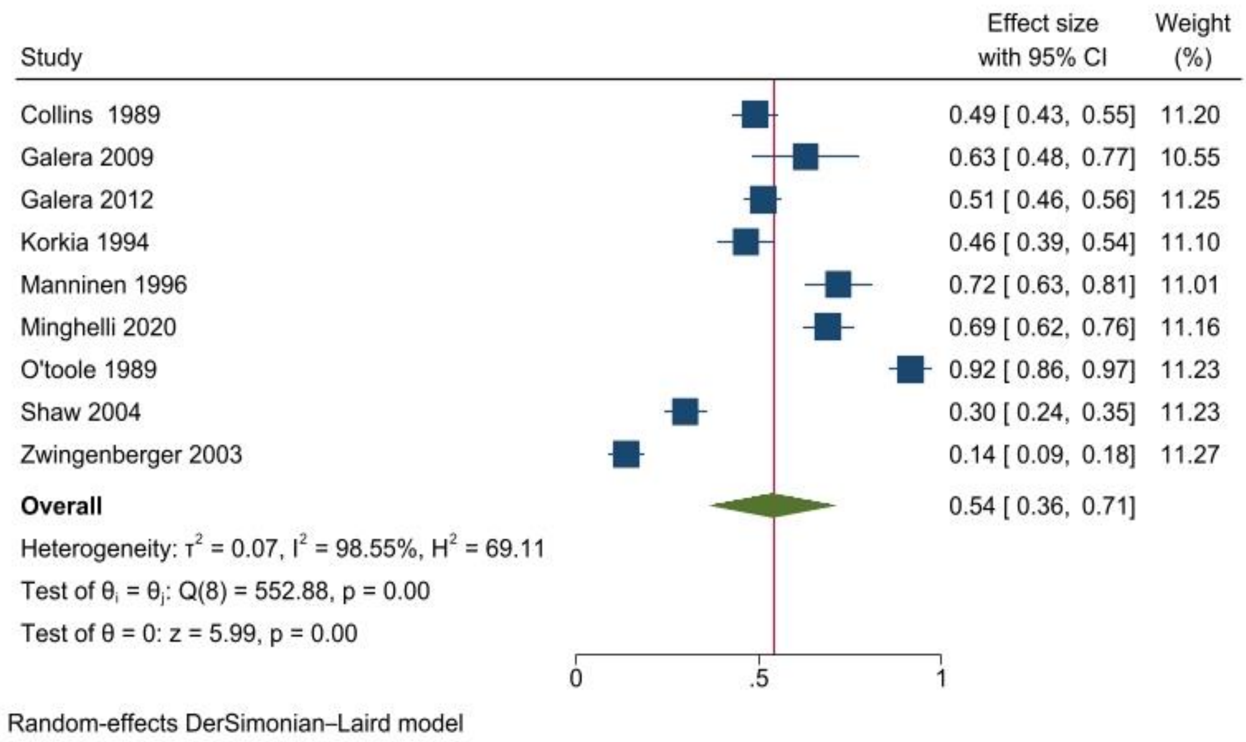
Shaw et al, 2004	One or more of the following consequences: A reduction in the amount or level of sports activity; a need for medical advice or treatment; adverse social or economic effects; a need to alter training to accommodate the injury	Not specified	Non-elite	258 (68/190) 35 years	30	----	----
Zwingenberger et al, 2013	The same was described by Egermann et al. (EGERMANN; BROCAI; LILL; SCHMITT, 2003) “An event taking place during training or competition since starting triathlon, which forced the athlete to stop the current training session or race.”	Ironman / Half-Ironman / Olympics / Sprint	Amateur	212 (43/169) 40.3 years	14	16	25

Abbreviations: F: female, M: male, SD: standardized deviation

Prevalence of injury in triathletes

According to a meta-analysis of nine studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; GALERA; GLEIZES-CERVERA; PILLARD; RIVIÈRE; SPORTS, 2009; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020; O'TOOLE; HILLER; SMITH; SISK, 1989; SHAW; HOWAT; TRAINOR; MAYCOCK, 2004; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there is a low level of certainty of evidence that the prevalence of injury at 12 months was 54 (95% CI 36 – 71%). An I^2 value of 98.5% indicated high heterogeneity between studies **(Figure 2)**.

Figure 2. Forest plot of overall injury prevalence in triathletes

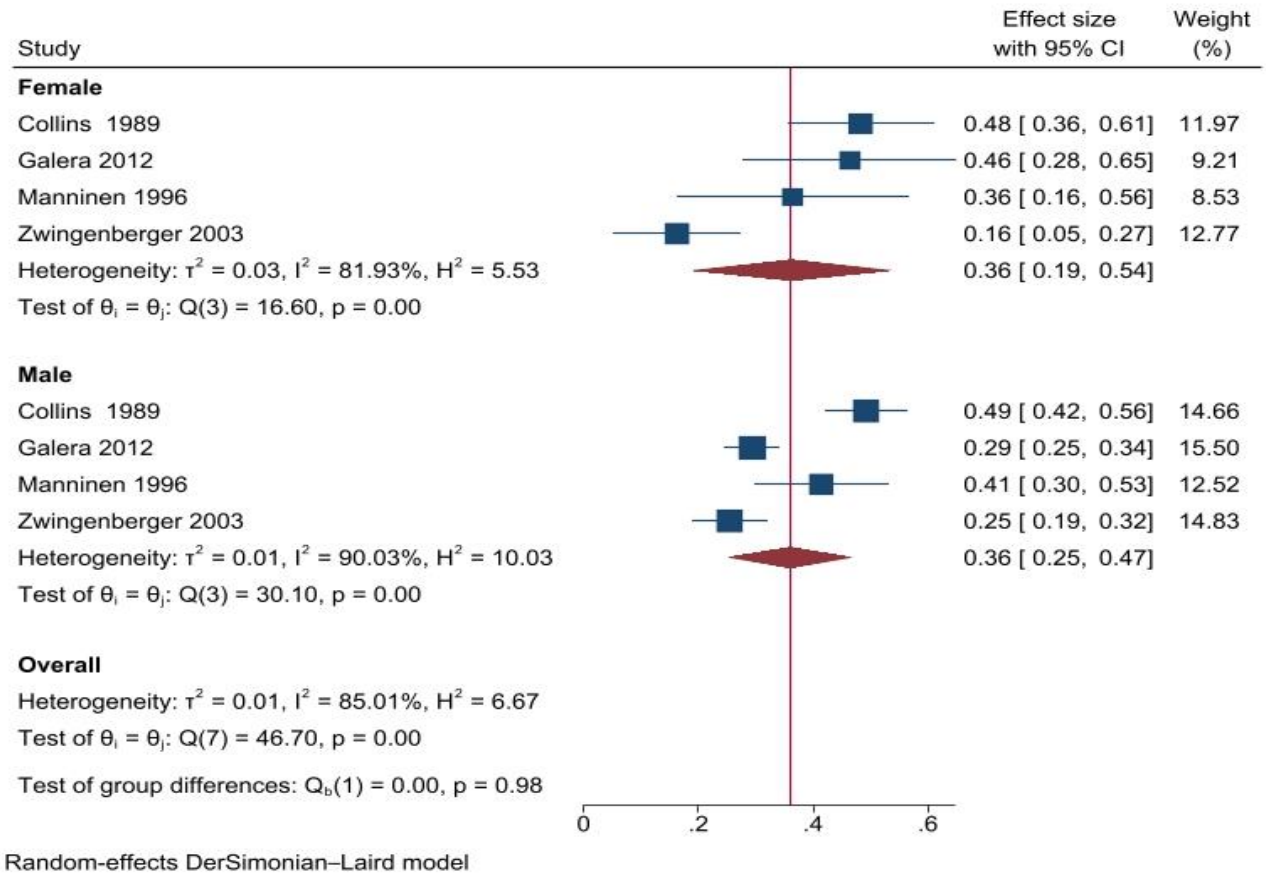


Prevalence of injury by sex

According to a meta-analysis of four studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; MANNINEN; KALLINEN, 1996; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there is a low level of certainty of evidence that the prevalence of injury in men at 12 months was 34 (95% CI, 30 - 37%), while the same studies showed the prevalence of injury in women at 12 months of 33 (95%

CI, 26 - 40%). The I^2 value was 0% for both men and women, indicating low heterogeneity in both groups **(Figure 3).**

Figure 3. Forest plot of injury prevalence separated by male and female subgroups



Prevalence of injury by body regions

Shoulder

According to a meta-analysis of six studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there is a low level of certainty of evidence that the prevalence of shoulder injury was 7 (95% CI 4 – 11%). An I^2 value of 66.7% showed high heterogeneity between studies **(Supplementary Material 2)**.

Knee

According to a meta-analysis of six studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there is a low level of certainty of evidence that the prevalence of knee injury was 24 (95% CI 20 – 28%). An I^2 value of 51.3% showed high heterogeneity between studies **(Supplementary Material 2)**.

Lumbar spine

According to a meta-analysis of seven studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020; O'TOOLE; HILLER; SMITH; SISK, 1989; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there is a low level of certainty of evidence that the prevalence of lumbar spine injury was 19 (95% CI, 8 – 29%). An I^2 value of 97% showed high heterogeneity between studies **(Supplementary Material 2)**.

Thigh

According to a meta-analysis of five studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020), there is a low level of certainty of evidence that the prevalence of thigh injury was 8 (95% CI, 2 – 14%). An I^2 value of 93.2% showed high heterogeneity between studies **(Supplementary Material 2)**.

Foot and ankle

According to a meta-analysis of seven studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; GALERA; GALERA; GLEIZES-CERVERA; PILLARD; RIVIERE, 2012; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MANNINEN; KALLINEN, 1996; MINGHELLI; JESUS; MARTINS; JESUS, 2020; O'TOOLE; HILLER; SMITH; SISK, 1989; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), 2014), there is a low level of certainty of evidence that the prevalence of foot and ankle injuries was 27 (95% CI 17 – 36%). An I^2 value of 92.7% showed high heterogeneity between studies **(Supplementary Material 2)**.

Hip

According to a meta-analysis of four studies (COLLINS; WAGNER; PETERSON; STOREY, 1989; KORKIA; TUNSTALL-PEDOE; MAFFULLI, 1994; MINGHELLI; JESUS; MARTINS; JESUS, 2020; ZWINGENBERGER; VALLADARES; WALTHER; BECK; STIEHLER; KIRSCHNER; ENGELHARDT; KASTEN, 2014), there was a low level of certainty of evidence that the prevalence of hip injury was 2 (95% CI 1 – 3%). An I^2 value of 0% showed low heterogeneity between studies **(Supplementary Material 2)**.

Risk of bias assessment

Assessment of the methodological quality of the included studies is presented in **Table 2**. The scores ranged from three to five points. Most studies (44%) reported a score of four. The criteria evaluated by the checklist most met among the included studies were an appropriate sample to address the target population (Item 1), a detailed description of the subjects and the setting of the research (Item 4), and use of valid methods to identify the injury condition (Item 6). On the other hand, the criteria evaluated by the checklist that was mostly absent among the included studies were adequate sample size (Item 3), data analysis conducted with sufficient coverage of the identified sample (Item 5), and adequate response rate (Item 9).

Table 2. The methodological quality of included studies

Item / **Study**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Scores (0-9)**
Collins et al., 1989	Y	N	N	Y	N	Y	U	Y	N	4
Galera et al., 2009	N	Y	N	Y	N	Y	U	N	N	3
Galera et al., 2012	Y	Y	Y	N	Y	Y	U	N	N	5
Korkia et al., 1994	Y	U	N	Y	N	Y	U	Y	N	4
Manninen & Kallinen, 1996	Y	U	N	Y	N	Y	U	Y	N	4
Minghelli et al., 2020	Y	U	N	N	U	Y	U	Y	U	3
O’toole et al., 1989	Y	U	N	Y	N	Y	U	N	N	3
Shaw et al., 2004	Y	Y	N	N	N	Y	U	Y	N	4
Zwingenberger et al., 2013	Y	U	N	Y	N	Y	Y	Y	N	5

Abbreviations: *Y* yes, *N* no, *U* unclear

No publication bias was observed in this study. The results of the Egger test were not significant (10.35; 95% CI: -13.45 – 34.14; p= 0.33).

DISCUSSION

This is the first review conducted to investigate the prevalence of injuries in triathletes. The results presented provide low certainty of evidence that the prevalence of injuries in triathletes is 56%. The prevalence of injuries in both men and women was similar (34%). The most affected anatomical sites were the foot and ankle, with 27%.

This review showed an injury prevalence in triathletes of 56%. In a cross-sectional study carried out by Almeida et al., (2015) with 257 swimmers, an overall prevalence of injury in the last year of 20% was found (DE ALMEIDA; HESPANHOL; LOPES, 2015). In a systematic review and meta-analysis performed by Borel et al., (2019), which included 3786 recreational street runners, an overall injury prevalence of 36.5% was found (BOREL; ELIAS FILHO; DIZ; MOREIRA; VERAS; CATHARINO; ROSSI; FELÍCIO, 2019). Regarding cycling, Decock et al., (2016) reported an occurrence of 29.5% of injuries in non-professional competitive cyclists (DECOCK; DE WILDE; VANDEN BOSSCHE; STEYAERT; VAN TONGEL, 2016). These data suggest a higher frequency of injuries in triathlon, possibly due to the accumulated overload of the three modalities (ROONEY; SARRIEGUI; HERON, 2020).

Heterogeneity may stem from each study's definition of injury, which varied across investigators. Some studies used different definitions, while others did not report the definition of injury used, which generates differences in injury rates between studies, corroborating the findings found in this review, which ranged from 36% to 71%. Therefore, a standard definition of triathlon-related injury may contribute to reducing wide variations in the observed injury rates.

Regarding the characteristics of the studies, the types of competitions and the experience of the triathletes were the main variables related to the emergence of injuries, as the competitions had different distances to be covered in the three modalities. The types of competitions to be held during a season are related to the training load, which is directly related to the risk of injury. A systematic review (KIENSTRA; ASKEN; GARCIA; LARA; BEST, 2017) highlighted the association between training load and injury incidence in many team sports, as increased training load puts athletes at greater risk of injury, which is present until four weeks after increasing the load. However, other studies point out that high training loads are a protective factor in some team sports and runners (DREW; FINCH, 2016), a modality that is present in triathlon.

The results of this review have several important practical implications. Considering that the prevalence of injuries suffered by triathletes remains high, it is necessary to implement prevention programs to apply the practice of triathlon, whether amateur or professional, safe, and healthy. Strategies to reduce injuries should be implemented for athletes at risk as well as making coaches and triathlon practitioners aware of this increased susceptibility, especially in the knee and ankle joints, regardless of sex. Such strategies could focus on modifiable injury risk factors, such as performing appropriate warm-ups, using appropriate sports facilities and equipment, performing triathlon-specific physical preparations, and adapting the training load to the athlete's ability.

To increase the level of evidence on the occurrence of injuries in triathletes, longitudinal studies with greater precision and an appropriate follow-up period to assess the incidence and associated factors are necessary to generate specific preventive strategies for this sport, focusing mainly on the lower limbs. As demonstrated in the assessment of the risk of bias in the studies included in this review (Table 2), it appears that most studies scored negatively regarding sample size, data analysis with sufficient coverage of the studied sample, and adequate response rates. To improve methodological quality, these items should be the focus of future studies.

CONCLUSION

The prevalence of injury was 54% among 2096 triathletes analyzed. Men and women demonstrated the same prevalence of injuries. The most affected anatomical sites were the foot and ankle (27%) and knee (24%). This systematic review provides important information for sports medicine specialists who make decisions regarding appropriate injury prevention measures. Injury prevention measures should be implemented to reduce the high prevalence rates in the triathlete population.

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DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

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