DO WE UNDERESTIMATE ANKLE SPRAINS IN RUNNING? A SYSTEMATIC REVIEW AND META-ANALYSIS

ABSTRACT

Objective: To provide a systematic review and meta-analysis of the proportion of ankle sprains in running practices.

Design: Systematic review and meta-analysis

Main outcome measures: We calculated the weighted summary proportion and conducted meta-analyses for runners, considering levels (elite/recreational) and disciplines (distance, track, cross-country, trail, and orienteering).

Results: 32 studies were included in the systematic review and 22 were included in the meta-analysis with a level of quality ranging from poor to good. proportion of ankle sprains in runners was 13.69% (95%CI = 7.40 - 21.54; I^2 = 98.58%) in global, 12.20% (95%CI = 5.24 - 21.53; I^2 = 89.31%) in elite, 19.40% (95%CI = 10.05 - 30.90; I^2 = 99.09%) in recreational, 8.51% (95%CI = 4.22 - 14.12; I^2 = 96.15%) in distance, 67.42% (95%CI = 0.50 - 82.85; I^2 = 99.36%) in track, 27.07% (95%CI = 12.48 - 44.81; I^2 = 97.97%) in cross-country, and 25.70% (95%CI = 19.87 - 32.14; I^2 = 0.00) in orienteering.

Conclusions: Running practice results in significant proportion rate of ankle sprains. Recreational runners exhibit higher proportion than elite. Running disciplines, especially track, cross-country, and orienteering, influence reported ankle sprain rates, surpassing those of distance runners.

Keywords: Running, epidemiology, sprains and strains, ankle injury.

INTRODUCTION

Running provides numerous health advantages, including aiding in weight management and promoting long-term maintenance of healthy lifestyle [1]. Moreover, running is associated with a reduced risk of mortality from all causes, especially cardiovascular, even at low doses, e.g., ten minutes a day [2]. Compared to sedentary individuals, runners have a 45% lower mortality risk, and their life expectancy is increased by three years in a cohort study [3]. Nevertheless, running is often linked to various running related injuries (RRIs) [4] with an overall incidence of 40.2% and an overall prevalence of 44.6% [5]. RRIs are commonly separated into two main categories: overuse and traumatic. Today, most studies are focused on overuse RRIs and their epidemiological data are well documented [4]. Mostly because up to 70% of RRIs are due to overuse. However, traumatic RRI may lead to a bigger financial burden when accounting direct (healthcare utilization) and indirect (absenteeism from paid work) costs [6].

Ankle sprain is the most common injury sustained in the physically active population [7]. This traumatic injury to ankle ligaments is sometimes regarded as a trivial injury that resolves spontaneously [8, 9]. However, a substantial proportion of people undergoing an ankle sprain experience injury recurrence and long-lasting symptoms that form chronic ankle instability (CAI) [8, 10] that may lead to ankle osteoarthritis [11]. Hertel et al. (2019) define CAI as a condition characterized by repetitive episodes or perceptions of the ankle giving way; ongoing symptoms such as pain, weakness, or reduced ankle range of motion (ROM); diminished self-reported function; and recurrent ankle sprains that persist for more than 1 year after the initial injury [10]. In a socio-economical view, each ankle sprain contributes to a work time loss estimated around 15 days [12], and the direct and indirect costs of ankle sprains are estimated to be over 1 billion dollars a year in the U.S.A. [13]. Together, ankle sprain and CAI may lead to inactivity and result in lower health related quality of life [14, 15]. In addition, time loss from competition or training may also hinder the performance of recreational and elite runners [16].

To our knowledge, no study already quantitatively analyzes the epidemiology of ankle sprains in running across different running disciplines and levels of practice. Yet, some running disciplines so as orienteering or trail are tough to be more prone to ankle sprains, due to their changes in ground surfaces, directions, and speed [7, 17]. This suggest that frequency of ankle sprains and its impact on running practice, and health may vary across running disciplines similarly to other RRIs. For example, Achilles tendon injuries are thought to range from 0.7 to 35 injuries per 1000 hours of running, in which trail runners are more prone to developing Achilles tendinopathy [18]. A better identification of ankle sprain epidemiology in running disciplines and levels of practice may lead to improve prevention strategies, reduce running dropouts among novice and competitive runners [19, 20], direct and indirect costs, time-loss and promote good health among recreative runners.

Consequently, the goal of this systematic review and meta-analysis is to present a quantitative analysis of ankle sprains in various running disciplines. A better understanding of epidemiological data regarding ankle sprain will offer a fundamental basis for the development of prevention and rehabilitation recommendations.

METHODS

The present systematic review and meta-analysis followed the preferred reporting items for systematics reviews and meta-analysis guidelines (PRISMA)(Appendice 1) [21]. The protocol was prospectively registered on PROSPERO (CRD42020218247) on the 12^{th} of December 2024.

Table 1. PICO and terms of the search equation		
	Key-terms	**Mesh-term and synonyms**
Population	Running	Running OR Jogging OR runner OR runner*
Intervention/Control	Ankle sprain	Ankle injuries OR ankle sprain*
Outcome(s)	Epidemiology	Incidence OR incidence rate OR prevalence OR prevalence rate

Eligibility criteria

Search strategy and studies selection

We searched the following databases without time restriction up to June 2023: MEDLINE (PubMed), Scopus, Cochrane, CINAHL, SPORTDiscus and Embase. The PICO search strategy is available in Table 1. Keywords of two search strings (runners and ankle sprain) were combined in the search equations. Search equations for each database are available in Appendix 1. Two independent investigators (XXX and XXX) conducted a blinded double stage study selection on Rayyan web app [22]. The articles identified were first screened based on their title and abstract. Conflicting results were resolved through consensus, and a third investigator (XX) was consulted in case of persistent disagreement. Then, the same process was repeated for full text selection.

To be included, articles had to be randomized or non-randomized clinical trials, longitudinal or epidemiological investigations. The articles had focus on assessing ankle sprains and RRI in runners, i.e., endurance, marathon, track, jogging, sprint, cross-country, trail, orienteering and triathlon runners. Articles evaluating track disciplines, as well as those examining multiple sports concurrently, were required to distinctly segregate their results based on specific sports and/or disciplines. Track and field studies had to clearly separate track (running) disciplines and field (jumping / throwing) disciplines. Animal and cadaveric studies were systematically excluded as well as reviews and opinion papers.

Data collection and analysis

One investigator performed data extraction (XX). Collected information was related to the authors, study design, outcomes, participant information (sample size, number of runners, level and discipline of practice), number of injuries, number of ankle injuries, number of ankle sprains, occupational workload, ground surfaces, history of injury, dominant foot, BMI, running experience, weekly mileage, and athletes' exposures. All types of ankle sprains were included. A runner was classified as elite if they competed at international level, national level or runs for a living. Disciplines were divided in six sub-groups: Distance, track, cross -country, orienteering, trail, and triathlon. Distance group included running disciplines longer than 800m running which were not included in the other categories, track group included track disciplines shorter than or equal to 800m running. Then, a second investigator (XXX) screened the extracted data and provided amendment, when needed. We manually extracted the number of runners if any study assessed multisport event or other athletes.

Risk of bias assessment

One investigator (XX) appraised the risk of bias of each included study with the modified Downs & Black Checklist. Then, a second investigator (XXX) provided amendment, if needed. The maximum scores are respectively 28 and 25 for randomized and non-randomized controlled trials. The quality classifications were excellent (26–28), good (20–25), fair (15–19) and poor (≤14) [23].

Meta-analysis

One investigator (XXX) performed statistical analyses with MedCalc® Statistical Software version 22.007 (MedCalc Software Ltd, Ostend, Belgium). The total numbers of running related injuries, and ankle sprains were manually collected by another investigator (XX). We then calculated the weighted summary proportion of ankle sprains among running-related injuries by conducting a Freeman-Tukey transformation. We calculated the proportion under a random-effect model to take account of the high degree of heterogeneity among studies. Finally, we performed proportion meta-analyses for runners in general as well as considering running level, i.e. elite or recreational, and running discipline, i.e., distance running, track, cross-country, trail, or orienteering.

RESULTS

Study selection

A total of 2814 articles were identified on the databases. Three other sources known by the authors were manually added [24-26]. After removal of the duplicates, we screened 1664 entries through title and abstract reading. Ultimately, we screened 190 articles based on their full texts. At the end of the process, 32 articles were included in the qualitative synthesis, and 19 in the meta-analysis (Fig.1).

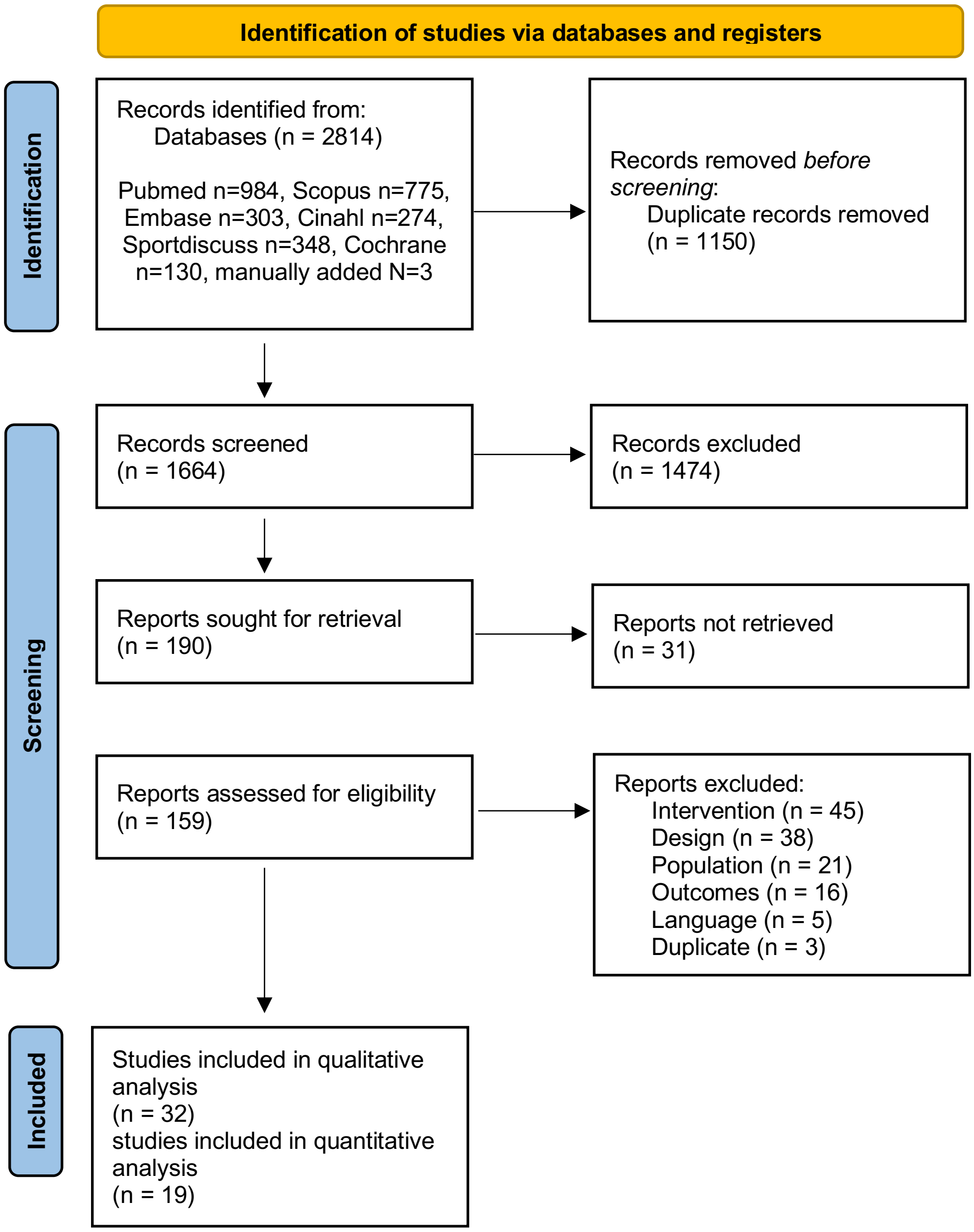

Figure 1. PRISMA flow chart

Characteristics of the studies

Among the included articles in the qualitative analysis, four were cohort studies [27-30], ten were prospective studies [16, 31-39], twelve were retrospective studies [40-51], two were cross-sectional studies [52-55], and two were randomized controlled trials [56, 57]. The characteristics of these studies are described in Table 2. The sample sizes ranged from 5 to 108 347 runners, with a total of 225 905 participants across all studies, among which 220 766 were runners. The remaining 5139 were basketball players, soccer players, hikers, or were track and Field athletes practicing a non-exclusively running discipline (i.e. long-jump). The participants included 202 141 cross-country runners, 15 560 track runners, 3509 distance runners, 389 triathlon runners, 144 orienteering runners, and 39 trail runners. Only one track and field study specified the specific disciplines practiced [29]. Among all running disciplines, 211 665 were elite athletes versus 10 117 recreational athletes. One study covering 2989 track athletes specified that elite and recreational athletes were included but did not mention their proportion [44].

Table 2. Summary of studies evaluating AS in running

Reference	Study design	Population	Mean age	Discipline	Level	Intervention	Outcomes
Altman 2015	Prospective	201 runners from online international survey	36,7	Running	Recreational	Monthly self-reported injury questionnaires	Total: 346 injuries ➔ 7 AS
Bishop 1999	Prospective	17 participants of the 1996 Colac 6-days race	47	Distance running	Recreational	Questionnaires 3 times per 24h followed by medical examination if injury report by 2 experienced physicians	Total: 36 injuries ➔ 0 AS
Bring 2018	Retrospective	183 runners of 3 high school and 3 division III colleges during the 3 seasons between 2013-2015	18,3	T&F / CC	Elite	Retrospective analysis of 3 previous studies, all evaluating demographic information, FMS scoring and injury tracking in the same way	Total: 117 injuries ➔ 14 AS
Chandran 2021	Retrospective	108347 women's CCrunners from 2014–2015 to 2018–2019 athletic season	/	CC	Elite	ATs at participating institutions voluntarily contributed exposure and injury data to the ISP using their clinical electronic medical record systems	Total: 429 injuries ➔ 18 AS
Dejong 2022	Cross-sectional	130 10 to 17 years old participating in CC, track running and/or long distance running	14	CC Distance T&F	Recreational	Questionnaire and physical assessment	Total: 73 injuries ➔ 73 AS
Fallon 1996	Prospective	32 participants of the 1990 ultramarathon of Melbourne	43	Distance running	recreational	Each runner was observed or contacted from 2 to 8 times a day. Medical examination was done if the runner asked for it. Data was collected at the same time	Total: 64 injuries ➔ 1 AS
Feddermann-Demont 2014	Prospective	Athletes during the 13 top-level international championships in Athletics	/	T&F	Elite	Examination of injuries during each championship by the team physician and the Local Organizing Committee	Total: 674 ➔ 11 AS
Fong 2008	Prospective	192 Attendances to the emergency of the hospital in Shatin (Hong Kong) from 1january 2005 to 31 December 2005	17.5	Running	Recreational	The triage nurse on duty classified every case by the category of injury	Total: 1715 ➔ 5 AS
Galera 2012	Retrospective	389 Senior and veteran triathletes	/	Running (triathlon)	Recreational	Anonymous questionnaire about traumas history during the past season	Total: 214 injuries ➔ 23 AS
Hamill 2022	Retrospective	1016 US trail runners	39	Trail	Recreational	Self-reported online survey	Total: 872 injuries

							➔ 172 AS
Hiemstra 2009	Retrospective	114 participants of the annual Comrades Marathon expo held in Durban	38,6	Distance running	Recreational	Participants were questioned about previous ankle injuries	Only ankle sprains were reported ➔ 38 AS
Iwamoto 2008	Retrospective	1120 athletes who consulted the Keio university sport medicine clinic from October 1992 to December 2006	21,7	T&F	Elite/ recreational	Orthopedic surgeons in the sport medicine clinic at Keio University Hospital assessed personal data of participants	Total: 1863 injuries (all sports) ➔ 17 AS (T&F)
Janssen 2017	RCT	31 Members of universities, sport clubs and physical therapy students in Amsterdam	26	Running	Recreational	Each participant was asked to wear 3 braces during sport. After every 3- week round, the athlete was asked to complete a questionnaire to evaluate the respective brace	Total: 71 ➔ 23 AS
Johannsen 1993	Retrospective	55 runners in the Danish junior and senior national team in orienteering	21,5	Orienteering	Elite	Detailed training diary daily including information on all injuries and infections	Total: 126 injuries ➔ 33 ankle injuries. The study didn't clearly report AS
Johansson 1986	prospective	89 Orienteering elite athletes from 4 Swedish colleges from July 1, 1983, to June 31 1984	17,5	Orienteering	Elite	Monthly self-reported injuries	Total : 68 injuries ➔ 16 AS (9M and 7 F)
Kerr 2016	Prospective	90804 collegiate student-athletes participating in men's and women's CCduring the 2009–2010 through 2013–2014 academic years	/	CC	Elite	ATs reported injuries in real time through their electronic health record applications through-out the academic year	Total: 476 ➔ 35 AS (24M and 11F)
Luciano 2012	Retrospective	8 Entrances in the hospital Universitario e Pronto-Socorro Municipal Taubate from June 2004 to January 2005	24,6	Running	Recreational	Self-reported questionnaire	Total: 8 ➔ 4 AS (3M and 1F)
Malliaropoulos 2009	Cohort	202 elite Greeks track and field athletes who suffered of acute lateral AS from January 1996 to December 2004	/	T&F	Elite	Rehabilitation protocol in 4 phases	Total: 36 ➔ 36 AS

Malliaropoulos 2018	A 17-year observational cohort study	144 elite Greeks track-and-field athletes	20	T&F	Elite	Clinical examination (stance and gait, palpation, range of motion, muscle strength testing and special diagnostic tests)	Total: 367 injuries ➔ 122 AS
Marshall 2020	Retrospective cross-sectional	681 secondary school athletes diagnosed with an injury that occurred during CC participation between 2009 and 2019	15,3	CC	Recreational	Athletes were diagnosed by an AT	Total: 681 injuries ➔ 139 ankle injuries, AS were not clearly identified
McKeon 2014	Prospective	3000 athletes of 7 high schools during the academic years 2007-08-09.	/	T&F	Recreational	AS and injury data were reported by the employed AT of the high schools	Total: 1532 injuries ➔ 13 AS (6M and 7F)
Messier 2018	Cohort	300 people who responded to a 12-month recruitment effort completed an eligibility questionnaire during a prescreening visit	/	Running	Recreational	2-year observation	Total: 234 injuries ➔ 8 AS
Nielsen 2014	Cohort	933 novice runners	/	Running	Recreational	A Year running follow-up: Running with a watch (Garmin FR 110) and neutral running shoes (Adidas Glide 2). They are instructed to start running two times a week as a minimum. They must wear their GPS watch at each training session and upload data to an internet-based database	Total: 254 injuries ➔ 7 AS (3M and 4F)
Olympia 2019	Retrospective	77 runners among running-related films	/	Running	Elite/ recreational	Running related documentary films review	Total: 46 injuries ➔ 7 AS
Ramskov 2018	RCT	447 healthy recreational runners between 18 and 65 years of with an iOS- or Android- based smartphone.	39,5	Running	Recreational	Randomized parallel-group design: ➔ (1) running schedule intensity (S-I) focused on increasing the weekly volume of running ➔ (2) running schedule volume (S-V) focused on increasing total weekly running volume. Specific injury diagnoses collected as secondary outcomes were used to test the hypotheses.	Total: 80 injuries ➔ 4 AS
Shah 2011	Prospective	200 participants of the 2009 national inter-	/	T&F	Elite	Injuries were attended on the field by 1 physical therapist	Total: 35 injuries ➔ 8 AS

		university athletic meet in Manipal, India.					
Watson 1987	Prospective	234 track runners from 17 track teams in the Illinois countries of Sangamon and Macoupin	15,8	T&F	Recreational	Coaches and/or athletic reported injury onset during the season. Authors examined all injured athletes	Total: 41 injuries ➔ 7 AS (4M and 3F)
Wiegand 2019	Cross-sectional	312 adults (< 18) runners or former runners	38	Running	Recreational	Online self-reported questionnaires	Total: 775 ➔ 60 AS
Williams 2001	Retrospective	40 runners	27,85	Running	Recreational	Self-reported questionnaires	Total: 134 ➔ 13 AS
Wu 2020	Retrospective	101 CC runners from middle school teams in the Boston area	12,45	CC	Recreational	Self-reported online questionnaire	Total: 63 injuries ➔ 12 AS (3M and 9F)
Wu 2021	Retrospective	2113 middle school CC runners from the state of Massachusetts	13,2	CC	Recreational	Self-reported online questionnaire	Total: 1110 injuries ➔ 464AS (271M and 173F)
Zang 2022	Cross-sectional	20 elite athletes from Guangdong provincial sports team	21,2	T&F	Elite	Self-reported questionnaire and physical assessment by physical surgeon	Total: 20 ➔ 17 AS

Abbreviations= RCT: randomized controlled trial; F: female; M: male; N/A: not assigned; AS: ankle sprain; T&F: track and field; CC: Cross-Country; HA: high arch; LA: low arch; AT: athletic trainer

Thirteen studies focused on distance running [28, 30, 34-36, 38, 40, 43, 45, 47, 52, 56, 57], eight on track [16, 27, 29, 31, 33, 37, 44, 55], five on cross-country discipline [39, 48-50, 53], two on orienteering [32, 42], one on trail [51], one on triathlon [58], one study included both track and cross-country disciplines [46] and another included track, cross-country and distance running [54]. Eighteen studies included recreational athletes [16, 28, 30, 31, 36, 38, 40, 41, 43, 45, 48, 49, 51-54, 56, 57], twelve studies included elite athletes [27, 29, 32-35, 37, 39, 42, 46, 50, 55] and two included both recreational and elite athletes [44, 47]. 22 studies included both men and women [29-32, 35, 37-39, 42-44, 46, 48, 49, 51-53, 55, 56, 58-61], One study included only women [50], one studie only included men [34], and six studies did not specify genders of participants [16, 27, 28, 33, 36, 45, 47]. About injuries, only eight studies separated RRIs and ankle sprains by gender [16, 28, 31, 32, 39, 44, 48, 49].

A total of 2015 ankle sprains were objectively reported. Among those ankle sprains, 1120 occurred during one of the six running disciplines, 787 in recreational athletes and 310 in elite athletes. The reporting of ankle sprains varied across running disciplines and levels of practice, with 37 ankle sprains documented without information on the level of practice but with details on the sport category. In contrast, 14 ankle sprains were reported with information solely on the level of practice. This difference resulted in a gap of 23 AS between running disciplines and levels of practice.

Risk of bias

Twenty-six studies had a poor-quality level [16, 27-29, 31-37, 39-50, 53-55], four studies had a fair-quality level [30, 38, 51, 52] and two studies had a good-quality level [56, 57]. The mean quality-level was poor (11.9/28) (Table 3).

Table 3. Risk of bias assessment in included studies

Studies	Down & Black Checklist (modified)																											
	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Johnasson 1986	8	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0
Watson 1987	5	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Johannsen 1993	8	1	1	1	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fallon 1996	8	1	1	1	0	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bishop 1999	8	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
Williams2001	13	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
Fong 2008	9	1	1	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
Iwamoto 2008	12	1	1	1	0	1	1	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0
Hiemstra 2009	8	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0
Malliaropoulos 2009	14	1	0	1	1	0	1	1	0	1	1	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	0
Shah 2011	8	1	1	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Galera 2012	9	1	1	1	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0
Luciano 2012	11	1	1	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0
Fedderman 2014	14	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0
Nielsen 2014	12	1	1	1	0	0	1	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0
McKeon 2014	14	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0
Altman 2015	17	1	1	1	0	2	1	1	0	0	1	1	1	0	0	1	1	0	1	0	1	1	1	0	0	0	0	0
Kerr 2016	13	1	1	1	0	1	1	1	0	0	0	1	1	0	0	1	1	0	1	0	1	0	0	0	0	1	0	0
Janssen 2017	21	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	0
Bring 2018	14	1	1	1	1	2	1	1	0	0	1	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0
Malliaropoulos 2018	12	1	1	1	0	1	0	0	0	0	1	1	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0
Messier 2018	17	1	1	1	0	2	1	1	1	1	1	0	0	0	0	0	1	1	1	0	1	1	1	0	0	1	1	0
Ramskov 2018	24	1	1	1	1	2	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0
Olympia 2019	5	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Wiegand 2019	16	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0
Marshall 2020	14	1	1	1	0	1	1	1	0	0	1	1	1	0	0	1	1	0	1	0	1	0	0	0	0	1	0	0
Wu 2020	9	1	1	1	0	2	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Wu 2021	11	1	1	0	0	2	1	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0
Chandran 2021	11	1	1	1	0	0	1	1	0	0	0	1	1	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0
Zhang 2022	10	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0
Hamill 2022	16	1	1	1	0	1	1	1	0	0	1	1	1	0	0	1	1	0	1	0	1	1	1	0	0	1	0	0
Dejong 2022	12	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0

Meta Analysis

In our meta-analysis, we found that the overall ankle sprain proportion among runners was 13.7% (Figure 2). Elite runners experienced a lower proportion (12.2%; Figure 3) compared to recreational runners (19.4%; Figure 4). When considering different running groups, track athletes had the highest proportion (67.4%; Appendice 2), followed by cross-country (27.0%; Appendice 3), orienteering (25.7%; Appendice 4), and distance runners (8.5%; Appendice 5). Results of the different meta-analyses are detailed in Table 4. Ankle sprains proportions among different level of practice and different disciplines are modelled in Figure 5. Meta-analysis was not feasible for trail, and triathlon due to the lack of studies focusing on these disciplines.

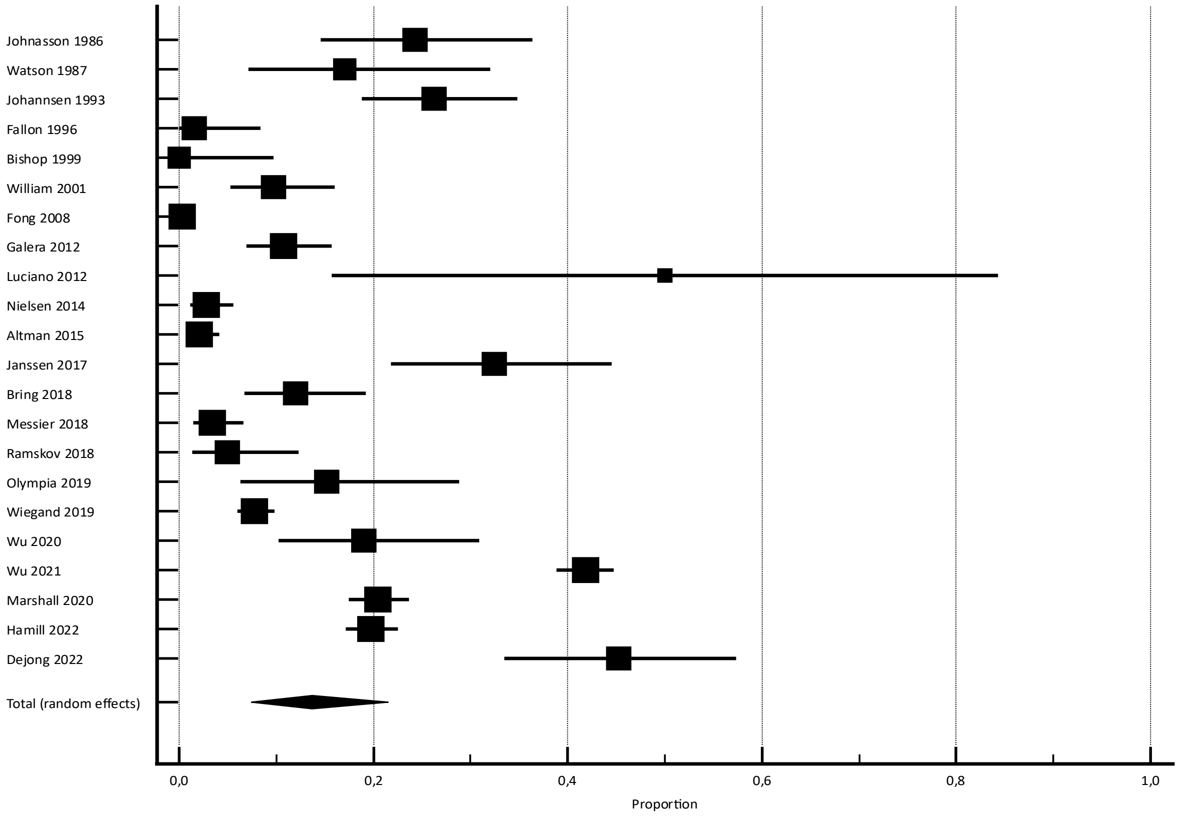

Figure 2: Forest plot of random effect model (representing proportion of AS across articles) of ankle sprain proportion of all runners

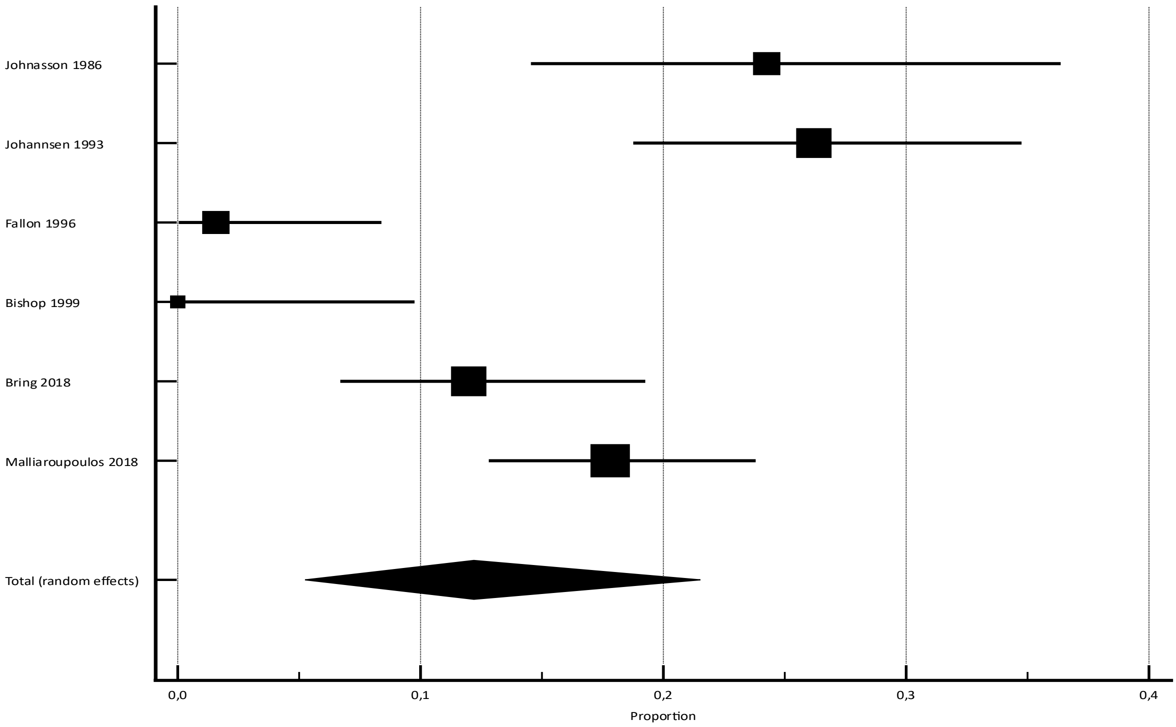

Figure 3. Forest plot of random effect of ankle sprain proportion of all elite runners

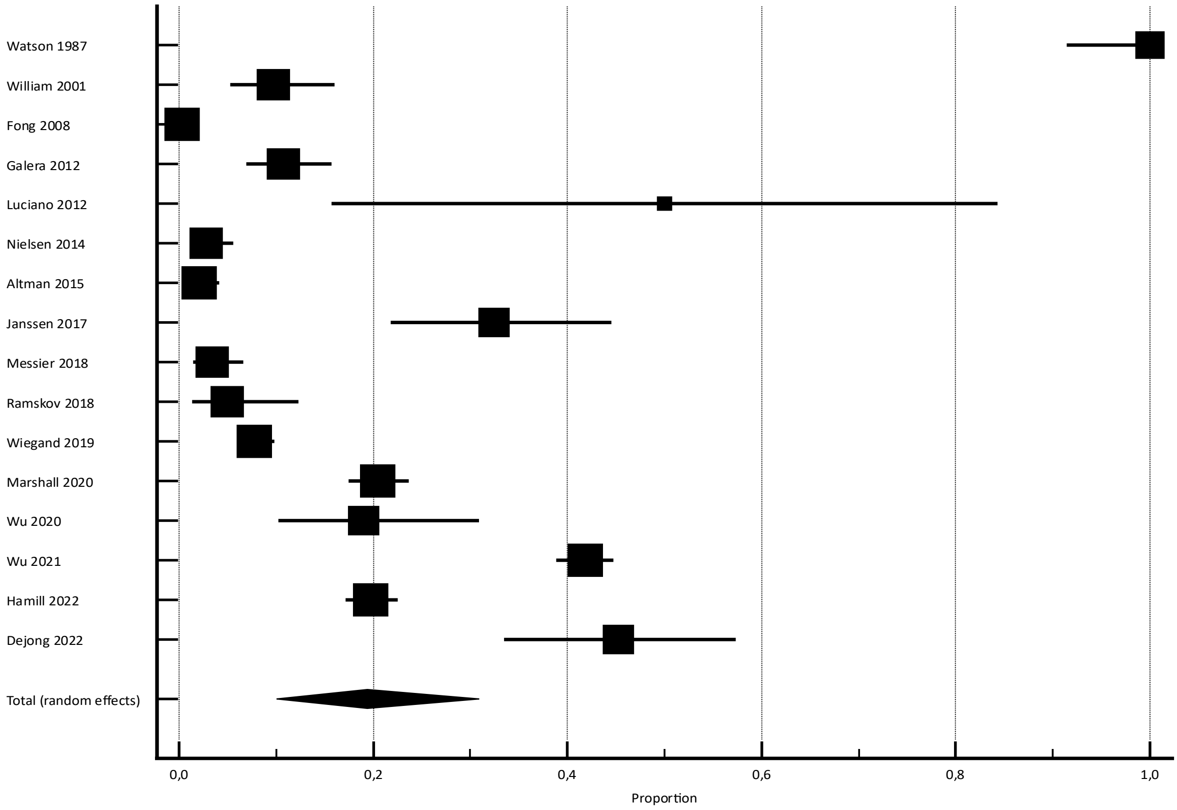

Figure 4: Forest plot of random effect model of ankle sprain proportion of all recreational runners

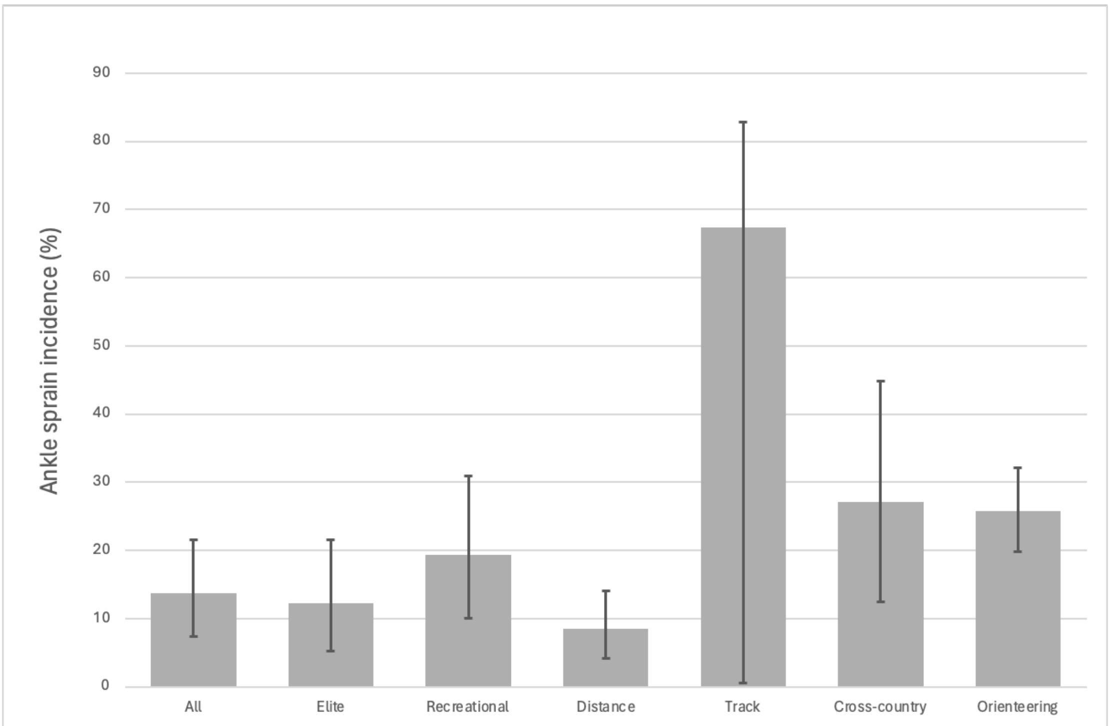

Figure 5. Ankle sprains proportions among different types of runners

Table 4. Comparison of ankle sprain proportions between running disciplines and level of practice

Subgroups	Studies (n)	Proportion (%)	95%CI	I2 (%)
All	22	13.69	7.40 - 21.54	98.58
Elite	6	12.20	5.24 - 21.53	89.31
Recreational	16	19.40	10.05 - 30.90	99.09
Distance	14	8.51	4.22 - 14.12	96.15
Track	2	67.42	0.50 - 82.85	99.36
Cross-country	3	27.07	12.48 - 44.81	97.97
Orienteering	2	25.70	19.87 - 32.14	0.00

Discussion

To the best of our knowledge, this is the first study to quantitatively analyze the proportion of ankle sprains across different levels and types of running practices. Ankle sprain has been identified as a significant RRI, with proportion rates observed to range from 8% to 67% of injuries. Notably, elite runners are found to have a lower likelihood of experiencing ankle sprains compared to recreational runners. These findings hold significance for medical practitioners, physiotherapists, sports trainers, and athletes who play a key role in the primary or secondary prevention of RRI.

The proportions of ankle sprains in running, as reported in our study, are lower or similar to those noted in other sports, such as soccer (21.2%)[7, 62], basketball (15.9%)[62-66], climbing (40%)[7], volleyball (45.6%) [7, 62, 63], dance (17.9%)[7, 65, 66], and gymnastics (32.3%)[7, 11, 65]. This comparison is intriguing, considering that the discourse around running injuries typically centers on overuse injuries, which constitute approximately 80% of RRIs. Nonetheless, ankle sprains, representing 13.7% of RRIs, manifest a proportion comparable to that of common overuse RRIs such as patellofemoral pain syndrome, Achilles tendinopathy, and medial tibial stress syndrome [4].

An ankle sprain sustained during running should be taken as seriously as an ankle sprain sustained in other sports, and as seriously as overuse RRI. More specifically, the 2016 consensus statement of the International Ankle Consortium argued the need for the implementation of effective prevention measures in running training protocols, as well as education among healthcare professionals regarding the prevention and rehabilitation of ankle sprain [8]. This is of utmost importance when considering the high rate of people developing CAI after an initial ankle sprain [67]. It has been estimated that the prevalence of CAI among elite track and field runners is approximately 60% [55]. Hertel et al. (2019) theorized that pathomechanical, sensory-perceptual and motor-behavioral impairments resulting from an initial ankle sprain contribute to the occurrence of CAI [10]. Diminished somatosensation, which is part of the sensory-perceptual impairments, include a higher dependance on visual information compared to somatosensory information during unipedal-stance balance tasks [68], and diminished active and passive joint position sense [69]. The inability to accurately sense their ankle joint position prior to initial ground contact during gait or landing is believed to elevate the risk of recurrent ankle sprain [70]. The consequence is that the foot is more likely to contact the ground in a manner that predisposes the ankle to move into supination, rather than pronation, during the loading response [70]. In addition, fear of injuring during movement (kinesiophobia) has been reported in CAI patients [14], which complicates the focus on therapeutic exercise as a primary treatment of CAI, presenting significant obstacle in its management.

Additionally, the literature recognizes rapid post-sprain changes in motor-behavioral functions, including altered muscle activation patterns and landing mechanics, which can contribute to the risk of further ankle sprains or other injuries [10]. The rehabilitation of these impairments has been shown to not only alleviate symptoms but also reduce injury risk, underscoring the potential benefits of rehabilitating lower limb dynamic function following an ankle sprain. Nonetheless, the specific link between motor-behavioral impairments and secondary overuse injuries warrants further investigation to fully understand the impact of rehabilitation on preventing subsequent injuries.

Our meta-analysis indicates that elite runners report fewer ankle sprains than recreational runners, a finding that diverges from some previous observations suggesting higher injury rates at more competitive levels [71, 72]. This discrepancy may be attributable to differences in study populations and definitions of competitive level. For example, variations in how ankle sprains are classified and diagnosed could contribute to the observed differences in reported proportions. Additionally, the scope and focus of included studies may differ, with some examining a broader range of running disciplines or runner characteristics. By focusing on runners specifically and considering the nature of ankle sprains within this context, our study offers nuanced insights into the injury dynamics within the running community.

Moreover, our analysis reveals a higher proportion of ankle sprains in track, cross-country, and orienteering runners compared to distance runners, likely due to the demands of these disciplines, such as rapid accelerations and running on uneven terrain [7, 65, 66, 73]. These methodological differences, such as varying assessment criteria and differing sample sizes across studies, can influence the observed proportions and should be considered when interpreting our results. This distinction underscores the importance of considering the specific demands and environments of different running disciplines when assessing injury risks [40, 62, 72-74].

The study, however, is not without limitations. These include the wide range of publication dates of included studies, potential biases due to the data extraction process, and the high heterogeneity among studies, which is common in proportion meta-analyses but can complicate interpretation. Despite these challenges, our findings highlight the global health significance of ankle sprains in running, given the sport's popularity. They advocate for the careful consideration of ankle sprains in both prevention and rehabilitation programs in running training. Moreover, the low representation of women makes gender generalization impossible. Furthermore, various factors, such as greater age [75], male biological sex [64], increased body mass index, asymmetries in functional muscle strength [76], history of previous injury [77], postural balance [78], and indoor, court and outdoor sports [66] are recognized to be risk factors of RRI. However, a very limited number of included studies reported these confounding factors, and none conducted an adjusted risk analysis focused on running related ankle sprains. Finally, the high risks of bias revealed by Downs & Black checklist scores and the high heterogeneity of the meta-analysis found among studies may also impair interpretation. However, such a high heterogeneity is typical in proportion meta-analysis [79] and is rarely a reason not to perform a meta-analysis [80].

Future research should aim to address these limitations through longitudinal prospective cohort studies with adequate sample sizes and comprehensive data collection. Such studies could provide more detailed insights into the incidence, risk factors, and prevention strategies for ankle sprains in runners, thereby informing more effective interventions and contributing to the well-being of the running community.

In conclusion, our study affirms the high frequency of ankle sprains among runners, with proportion comparable to those of other overuse RRIs. It reveals a lower proportion of ankle sprains among elite runners compared to recreational runners, and among distance runners compared to those in track and cross-country disciplines. Healthcare and sports professionals, as well as running stakeholders, are advised to take ankle sprains into serious consideration in monitoring and managing RRIs. Effective prevention and rehabilitation of ankle sprains are essential to mitigate their impact on running practice and performance.

Authors declare having no competing interest.

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Appendix 1: Search equations used on databases

Database	Search equation
Pubmed	("running"[MeSH Terms] OR "running"[Title/Abstract] OR "runner*"[Title/Abstract] OR "run"[Title/Abstract] OR "jogging"[Title/Abstract] OR "jog"[Title/Abstract] OR "jogger*"[Title/Abstract] OR "marathon*"[Title/Abstract] OR "sprint*"[Title/Abstract] OR "track and field"[MeSH Terms] OR "track and field"[Title/Abstract]) AND ("ankle injuries"[MeSH Terms] OR "sprains and strains"[MeSH Terms] OR "ankle injur*"[Title/Abstract] OR "ankle sprain*"[Title/Abstract] OR "sprained ankle*"[Title/Abstract] OR "ankle strain*"[Title/Abstract] OR "ankle distorsion*"[Title/Abstract])
Scopus	running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint* OR {track and field} AND {ankle injury} OR {ankle injuries} OR {sprains and strains} OR {ankle sprain} OR {ankle sprains} OR {sprained ankle} OR {sprained ankles} OR {ankle strain} OR {ankle strains} OR {ankle distorsion} OR {ankle distorsions}
Embase	('running':ti,ab,kw OR 'runner*':ti,ab,kw OR 'run':ti,ab,kw OR 'jogging':ti,ab,kw OR 'jog':ti,ab,kw OR 'jogger*':ti,ab,kw OR 'marathon*':ti,ab,kw OR 'sprint*':ti,ab,kw OR 'track and field':ti,ab,kw) AND ('ankle injuries':ti,ab,kw OR 'sprains and strains':ti,ab,kw OR 'ankle injur*':ti,ab,kw OR 'ankle sprain*':ti,ab,kw OR 'sprained ankle*':ti,ab,kw OR 'ankle strain*':ti,ab,kw OR 'ankle distorsion*':ti,ab,kw)
Cinhal	**TI** running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field" OR **AB** running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field" OR **MJ** running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field" **AND TI** "ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*" OR **AB** "ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*" OR MJ "ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*"
SportDiscus	(TI (running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field") OR AB (running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field") OR KW (running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field")) AND (TI ("ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*") OR AB ("ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*") OR KW ("ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*"))
Cochrane	**TI/ Abtract / Keywords** running OR runner* OR run OR jogging OR jog OR jogger* OR marathon* OR sprint OR "track and field" OR **Mesh** : Running OR Track and Field AND **TI / Abstract / Keyword** "ankle injuries" OR "sprains and strains" OR "ankle injur*" OR "ankle sprain*" OR "sprained ankle*" OR "ankle strain*" OR "ankle distorsion*" OR **Mesh** : Ankle Injuries OR Sprains and Strains