Occurrence of acute respiratory illnesses in athletes: a systematic review and meta-analysis

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ABSTRACT

Background: Estimating the occurrence of acute respiratory illness (ARI) in athletes is crucial for understanding the need for preventive measures. This study aimed to estimate the occurrence of ARIs in athletes compared to non-athlete controls. We evaluated which of the published studies on the occurrence of ARI in athletes were eligible, giving due consideration to the epidemic nature of viral ARIs.

Methods: We performed a systematic search of PubMed, EBSCOhost, and Web of Science databases from January 1990 to May 2023. Only studies reporting the occurrence of ARIs in athletes, with a duration of at least 12 months and simultaneously employing non-athlete controls, were included. The random effects model was used to calculate the incidence rate ratio (IRR) of ARI in athletes compared to non-athlete controls, with 95% confidence intervals.

Results: Our search yielded 218 results, of which 6 studies met the essential criteria for viral ARIs and were included in our meta-analysis. Since the exact number of ARIs was not reported in many studies, we had to estimate the total number of ARIs for both athletes and non-athlete controls. The occurrence of ARIs was 1.87 times higher in athletes compared to non-athlete controls (3.2 vs 1.7, pooled IRR 1.87, 95% CI 1.08 to 3.26). Publication bias analysis or a funnel plot was not evaluated because the primary objective of none of the studies was to determine the occurrence of ARI in athletes. Most of the studies on the occurrence of ARIs in athletes had a duration of less than 12 months and did not include a concurrent control group, making them ineligible considering the seasonal and contagious nature of ARIs.

Conclusion: Our meta-analysis suggests that athletes suffer from significantly more ARIs than non-athletic subjects. Our observations highlighted the lack of high-quality long-term studies on the occurrence of ARIs in athletes.

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INTRODUCTION

Acute respiratory illnesses (ARIs) are the most common complaints in athletes, especially during major sports events, accounting for up to 50% of all medical consultations (23). In clinical practice, ARIs are usually classified as viral upper respiratory tract infections ("common cold") (136, 138). At the Olympics and World Championships, an ARI may ruin the long-term goal of an athlete. The occurrence and the disease burden are, however, both controversial (14, 113). In many studies, the occurrence during major sports events has been 2-5 % (2, 37, 119, 120), which is consistent with or even lower than in the general population (7, 129). In contrast, some recent studies have reported a physician-verified ARI of 38-45 % in athletes during major winter sports events (136, 138). The reasons for this disagreement are not well explained. Laboratory identification of the virus is the gold standard for verification of ARIs, but this is rarely performed in studies of athletes (19, 123, 138). Post the COVID epidemic, the increasing use of rapid diagnostics for point-of-care testing may address this lack of information, at least for common respiratory viruses.

Understanding the occurrence of ARIs in athletes is crucial for determining the proper prevention measures for reducing the burden of illness as well as for non-pharmaceutical interventions to minimize the contract and transmission of viral ARIs within sports teams (138). A recent systematic review and meta-analysis by a subgroup of the International Olympic Committee (IOC) consensus reported an annual ARI incidence of 1.7 in athletes (23). The IOC review reported a lower incidence of ARIs in elite athletes compared to non-elite athletes (23). These rates are comparable to, or even lower than, those in the general population. In 3 studies of young adults, the annual occurrence of ARI ranged between 2.3 and 4.6 (7, 13, 69).

To determine the incidence rate ratio of ARI in athletes compared to non-athlete controls, we performed a meta-analysis of the strictly selected studies published between January 1990 and May 2023.

METHODS AND SELECTION RATIONALE

Requirements for considering studies for meta-analyses of viral ARIs

The duration of the study should be at least 12 months to cover all annual outbreaks of the numerous respiratory viruses (*Table 1*). Most respiratory viruses annually display marked seasonal variation. For example, influenza epidemics occur in the Northern Hemisphere during the winter months and in the Southern Hemisphere during the summer months of the Northern Hemisphere (6, 86). The epidemics last 2-4 months and between epidemics the occurrence falls to near zero. The most common respiratory virus, rhinovirus, can be detected throughout the year, but distinct peaks occur in early autumn and late spring (43, 67, 75, 104). Finally, in some countries like Finland, respiratory syncytial virus (RSV) epidemics occur only every other year in 2-year cycles (108, 143). Therefore, if the study is conducted outside or during an epidemic, the study could result in either an underestimation or an overestimation of the occurrence of ARIs. The timing of epidemics may vary by weeks even in close geographical areas. Thus, athletes and controls may seem to have contracted a different number of ARIs in a study with only a short follow-up time.

A concurrent control group is needed when examining the occurrence of ARI in specified groups. The incidence of respiratory viruses varies from year to year. For example, the seasonal incidence of influenza is often approximated to be 5%-20% (132). Non-athlete controls should be matched for age and sex, and their weekly exercise should be known. In elite athletes, the mean training volume varies from 15-20 hours per week compared to less than 6 hours in the normal population (70, 107).

The prospective nature of the study is essential. It is difficult for anyone to reliably remember how many infections they have had even during the previous month. Athletes and controls might recall these differently, causing a recall bias in the results.

In clinical practice, ARI episodes among athletes are usually classified as common colds i.e., mild, self-limiting, viral upper respiratory tract infections (113, 136, 138). Symptoms typically include an acute onset of a sore throat, sneezing, a runny nose, nasal congestion, and a cough. Fever is usually absent or mild (60, 77). Flu-like illnesses with fever, muscle aches, and fatigue are rare (77). It is recommended that questions regarding all these symptoms be included in a standardized symptoms diary. Reminder emails for missing reports are essential. Web-based monitoring of study subjects has rarely been implemented (7, 49). In a study utilizing internet-based syndrome monitoring for ARIs in the general population of Germany, the participants received a weekly questionnaire via email to assess whether they had experienced an ARI in the past week (7).

Respiratory viral infections may occur as asymptomatic, paucisymptomatic, or symptomatic. A laboratory-based study in which 502 university students were followed for 8 weeks (September-October) found that the incidence rate of human rhinovirus was 8.3% per week for asymptomatic students (53). In a multicenter prospective cohort study of healthcare workers, the percentage of asymptomatic and paucisymptomatic influenza A cases was 47% and 42%, respectively (9). Similar observations were made in a community-based study, where 13% and 11% of 235 virologically confirmed cases of influenza virus infections were paucisymptomatic and asymptomatic, respectively (66). A study on 398 aquatic elite athletes, who had had SARS-CoV-2 infection, found that 54% had had a mild infection and 17 % reported no symptoms (70). One study found that having only 1 symptom for 1 day can prove to be a virus-positive ARI (136). In the occurrence studies on athletes, commonly used symptom algorithms, such as the Wisconsin Upper Respiratory Symptoms Survey (WURSS) or the Jackson Cold Scale, both require at least 2 symptoms that last for at least 2 days to diagnose an ARI; consequently, this may inadvertently exclude a marked percentage of ARIs. These algorithms may no longer be fit for purpose in assessing ARIs in athletes. The Jackson Cold Scale was established in 1958 and the WURSS was not originally planned for diagnostic purposes but for a health-related quality of life questionnaire. Neither of these algorithms has been virologically validated. The World Health Organization (WHO) defines ARI as the sudden onset of symptoms of a sore throat and/or runny nose, and/or cough, with at least one of these symptoms being present (146).

ARI can be diagnosed clinically. Viral diagnostics can be used to confirm a viral ARI. Commercial multiplex PCR tests covering 16-18 viruses, are simple, sensitive, and reliable and have also been used as point-of-care tests. The viral etiology of an ARI can be established in 70-90% of cases in athletes (89, 111, 136, 138). In contrast, 2 previous studies assessing the viral etiology of ARIs in elite athletes found confirmed ARI incidences to be only around 30% (19, 123). Different respiratory viruses cannot be distinguished by their clinical features alone (44, 76).

The motivation to report all symptoms should be the same among athletes and controls. Active and regular viral diagnostics can be used to verify this. Discrepancies between the number of viral findings and the reported symptoms between the compared groups could indicate that there is reporting bias.

Data sources and search strategy

The review and protocol were not registered but were conducted according to published Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (96). Three databases, comprising PubMed, EBSCOhost, and Web of Science, were searched for studies published between January 1, 1990, and May 31, 2023. The following search phrase was used: ("acute respiratory illness*" OR "respiratory infection*" OR "respiratory tract infection*" OR "common cold*") AND (athlet* OR sport* OR exercis*) AND (prevalence* OR incidence* OR occurrence*). References that were potentially eligible after screening the title and abstract were reviewed and evaluated for inclusion via the full text. Further, additional papers were identified based on the reference list of relevant papers including review articles. The 124 studies included in the meta-analysis of the IOC report (23) were reanalyzed separately, with due consideration given to the contagious and seasonal nature of ARIs.

Inclusion and exclusion criteria

Studies were included for meta-analysis if they fulfilled the following criteria: (1) the duration of the study was at least 1 year, and (2) the study simultaneously included non-athlete controls. Because of the low number of prospective studies, retrospective studies that met the above criteria were also included in the meta-analysis. Studies that did not present any original data (reviews, editorials, etc.) were excluded. Only English-written reports were included (Figure 1). A common quality assessment of the included articles was undertaken using the Newcastle-Ottawa scale (145). Disagreements between authors were resolved by regular group discussions.

Data extraction

The following data were extracted from each of the included studies: the number of participants in each group, the duration of the study, and the number of ARI cases. One author extracted the data while a second author cross-checked the collected data.

There was only one study that reported the exact number of ARIs in athletes and non-athletes (12), and one study that reported the monthly number of ARIs per individual (61). The number of ARIs was determined by multiplying the monthly mean number of ARIs by the number of individuals in the group. One study reported the percentage of athletes and controls with ARI at 8 time points (38). In this study, the number of ARIs was determined by summing the total number of individuals with ARIs at each point. Two studies reported that individuals experienced either ≤2 episodes, 3-4 episodes, or ≥5 episodes (134, 135). We determined that individuals had either 1.5 episodes, 3.5 episodes, or 6 episodes, respectively. A further study also reported the number of ARIs similarly, and therefore we determined that individuals who reported 1-2 episodes were classified as having 1.5 episodes and individuals who had 3 or more episodes were classified as having 4 episodes (16).

Statistical analysis

The studies were pooled together in the meta-analysis. A random-effects model was chosen because of the expected heterogeneity between the studies. An incidence rate ratio (IRR) with 95% confidence intervals (CIs) was calculated. A StatsDirect version 3.3.6 was used in all the statistical analyses (StatsDirect Ltd, Wirral, UK).

Table 1. Requirements for a study included in meta-analyses of the occurrence of acute respiratory infections in athletes (see section 2.1). ARI = acute respiratory illness.

1. ESSENTIAL REQUIREMENTS
Simultaneous non-athlete controls
Duration of the follow-up at least one year
2. OTHER ASPECTS TO BE CONSIDERED
Weekly (online) monitoring using standardized symptom diaries
Athlete's exercise types and durations are homogenous
Standardized definition of ARI
Viral diagnostics of illness episodes
Motivation to report all symptoms should be the same among athletes and controls

RESULTS

The analysis of the 6 studies in the meta-analysis based on the selection criteria of the study

Our database search identified 1399 records. These were supplemented with 95 articles identified via references in relevant articles. Altogether 218 studies reported the occurrence of ARI in athletes. From these 218 studies, 192 did not include simultaneous non-athlete controls and were therefore excluded. A further 18 studies were then excluded because the duration of the follow-up was less than 1 year. In total, 8 studies fulfilled the essential requirements. One study did not report the number of ARIs in the control subjects. One study was excluded because the population was already included in another study. Finally, 6 studies were included in the meta-analysis (Fig. 1, *Table 2*) (12, 16, 38, 61, 134, 135). The total number of athletes and non-athletes included in the meta-analysis was 388 and 344, respectively. Six different sports were covered: track and field (number of subjects, n=199) (16), football (n=75) (38), swimming (n=40) (134), wrestling (n=40) (135), cross-country skiing (n=19) (61), and triathlon (n=15) (12). Determining the occurrence of ARI in athletes was not the primary objective of any of the studies but rather, for example, the aim was to evaluate secretory immunoglobulin A or to determine vitamin D levels (38, 134, 135). Therefore, a publication bias analysis and a funnel plot were not evaluated.

In 4 of 6 studies included in the meta-analysis, the occurrence of ARI was significantly higher in athletes than in the non-athlete controls (Fig. 2) (38, 61, 134, 135). In the meta-analysis, the combined IRR (athletes vs. controls) was 1.87 (CI: 1.08-3.26). The annual frequency of ARI episodes was 3.2 in athletes and 1.7 in the non-athlete controls. Three studies were prospective (12, 38, 61), and the other three were retrospective (*Table 2*) (16, 134, 135). In 2 prospective studies, participants were monitored either daily or weekly using a symptom diary or log (12, 38). In 1 prospective study, two-thirds of the cases were verified by a physician, and the remainder were based on self-reported symptoms by the subjects (61). None of the studies defined ARI as paucisymptomatic (1 symptom only) or lasting only 1 day. In addition, none of the studies identified the etiology of the ARI.

The additional assessments of other supplemental studies

Four studies out of the 218 studies originally analyzed, but none in the meta-analysis used etiological diagnostics (3, 54, 123, 138). One study did not investigate the viral etiology of ARI; instead, it focused on an outbreak of group A Streptococcal pharyngitis among university students in a judo club (3). In another study, where symptomatic athletes were screened only for influenza during the 2002 Winter Olympiad, influenza A/B was diagnosed in 13 of 46 athletes (54). Two other studies investigated multiple respiratory pathogens. In one study of elite summer sport athletes conducted in Australia, infectious agents were identified in only 29% of the ARI episodes (123). In contrast, another study of elite winter sport athletes confirmed the viral etiology of ARI in 75% of the cases (138).

In a reanalysis of the IOC meta-analysis, we found that 4 out of the 124 studies included were eligible when considering the seasonal and contagious nature of ARIs (12, 16, 23, 38, 135). Five studies lasted for 1 year or more (12, 16, 38, 62, 135). The duration of 80 of the studies was 3 months or less (1-5, 10, 11, 20, 22-28, 30-37, 39, 41, 42, 44, 46-48, 51, 52, 54-59, 64, 65, 71, 72, 76, 79, 80, 83, 84, 87, 88, 90-94, 97, 99, 100, 102, 103, 105, 106, 109, 110, 113, 114, 116, 119, 120, 122, 124, 125, 127, 130, 131, 133, 139, 140, 144, 147, 148). Ten studies included a concurrent control group (12, 16, 38-41, 106, 109, 123, 135). One study also defined ARI as paucisymptomatic (138).

Due to the low number of controlled studies, we analyzed 8 uncontrolled studies but with a duration of 12 months or longer (*Table 3*). In 343 athletes the mean number of ARIs per person per year was 2.8 (range 0.2–8.4) (8, 17, 21, 29, 63, 68, 128, 149).

DISCUSSION

The occurrence of ARIs in athletes

We found 6 studies on the occurrence of ARIs in athletes that were controlled and lasted for 12 months or longer. The annual mean number of ARI episodes in athletes was 3.2, compared to 1.7 in the control subjects. In 8 uncontrolled studies with a duration of 12 months or more, the mean number of ARI episodes was 2.8 per year (*Table 3*). Our meta-analysis suggests that athletes suffer significantly more ARIs than non-athletic subjects (IRR 1.87). Our observations showed the lack of high-quality long-term studies on the occurrence of ARI in athletes. None of the studies included in the meta-analysis was specifically designed to evaluate ARI occurrence among athletes, and controlled studies on this topic remain limited.

Our observations differ from those of the IOC consensus report (23). Their technically well-executed analysis demonstrated a lower incidence of ARI among athletes, 4.7/1000 athlete days converted to approximately 1.7 ARIs per athlete per year compared to 3.2 in our analysis. The IOC report is the cornerstone analysis of ARIs in athletes but the studies included can be criticized for several reasons although the investigators considered 89% of the 124 studies excellent or good. Only 8 studies aimed to evaluate the occurrence of ARIs (72, 96, 106, 121, 123, 128, 138). The major limitation of the studies was the short duration not taking into account the seasonal and contagious nature and risk factors of viral ARIs. The studies carried out only during summer months may underestimate the occurrence of ARIs and studies carried out only during winter months may overestimate the occurrence. Furthermore, the varying admission criteria are subject to an error. The heterogeneity of disciplines is also a source of bias. Summer sports and team sports should be analyzed separately. In all studies, the inaccurate nature of self-reporting is an important weakness.

Our findings are consistent with the systematic review of Moreira et al., which reported on 30 studies published before 2009 (with 8575 athletes and 1789 non-athletes) (85). The review found that athletes experience a higher rate of ARIs after training and competitions compared with less active individuals. Due to the high heterogeneity among the studies, Moreira and colleagues did not perform a meta-analysis. Hence, they refrained from providing numerical data regarding the occurrence of ARI among athletes and non-athletes (85).

The major limitation of our analysis is the low number and low quality of the studies included. Only 1 of the studies reported the exact number of ARIs in each group. For the remaining studies, we had to estimate the total number of ARIs in athletes and non-athletes. None of the studies defined ARI as paucisymptomatic or lasting only 1 day. Thus, a marked number of ARIs may have gone unrecorded. The retrospective nature of the 3 studies included in this meta-analysis might have hampered the number of ARIs. The meta-analysis included only 6 studies and had a small sample size (388 athletes and 344 non-athletes). Because of this, different sports disciplines, which may have differing effects on susceptibility to ARIs, could not be analyzed. The included studies covered only 6 different sports, and, for example, endurance athletes were not included. The primary objective of none of the studies was to determine the occurrence of ARI in athletes. For this reason, we did not report the publication bias analysis or the funnel plot. Furthermore, 95 studies were identified through sources other than database searching, suggesting that some studies may not have been identified.

Risk factors and effects of ARI

Vigorous and prolonged exercise temporarily suppresses the immune functions, and it has been believed to increase the risk of ARI in athletes (50, 73, 95, 115, 117), but its clinical meaningfulness has been questioned (14). A recently conducted systematic review found no evidence of detrimental effects from vigorous physical activity lasting up to 600 minutes per week (15). Many behavioral factors such as frequent use of public transportation and air travel, human crowding, shared housing and shared meals during training camps and competitions, full-contact sports, heavy breathing, and shouting by infected individuals during the game and in the locker room, are likely to increase the transmission of viral respiratory infections in athletes (77, 112); all of these being aspects that were ascertained as important during the COVID-19 pandemic. For example, Finnish elite athletes who competed in the 2019 Nordic World Ski Championships in Seefeld, Austria, had a 7-fold increase in the risk of ARI compared with control subjects exercising normally in Finland (136). During the 14-day study period, 38% of 26 athletes and 6% of 52 control subjects experienced symptoms of ARI. Compared with the support staff, who shared many risk factors with the athletes and of whom 17% of 36 reported ARI, athletes had a 2-fold risk of ARIs (136). Non-pharmaceutical interventions, such as the wearing of face masks, enhanced social distancing, and hand hygiene, can help to mitigate the contract and transmission of viral ARIs within sports teams (141). In addition, for athletes with recurrent infections, factors affecting immunity, such as diet and excessive psychological and physical stress, should be evaluated.

Psychological stress, sleep disturbance, fatigue, and nutritional deficiency may increase susceptibility to ARIs in athletes (14, 18, 101). A study investigating a cohort of elite young basketball players over 4 weeks during a competitive training period found a significant correlation between sources and symptoms of psychological stress and the total number of occurrences of ARI in the second week (84). During that week, participants had a greater source of psychological stress, and they reported a higher number of episodes of ARI (84). Similarly, another study of collegiate swimmers found that an increase in stress was associated with an increase in the ARI rate (142).

Age also affects susceptibility to respiratory viral infections. Adults aged 20-39 have higher rates of ARIs compared to the rate in adults over 40 (13, 82). Surprisingly, the IOC subgroup's meta-analysis, which included athletes up to 65 years old, found that the annual ARI incidence in athletes under 35 (5.9%) was about half that of athletes over 35 (9.2%) (23). Additionally, ARIs are more common in young adult women than in men of the same age which is likely to be related to greater exposure to young children (82). Indeed, children younger than 5 years of age in the same household are a major risk factor for virus transmission (13, 81, 82, 126). In a household-based surveillance study, the mean number of ARIs per person per year was 6.1 for children aged <5 years, and they were virus-positive for half of the year (13). Therefore, the number of children under 5 in an athlete's family should be known.

The type of sport and exercise may affect susceptibility to ARIs. Endurance exercise with a high cardiorespiratory component such as cross-country skiing, cycling, and running may cause a different susceptibility to infections than team sports and full-contact sports which involve close heavy breathing and shouting. For example, in one recent study on swimmers, open water swimmers were the least likely to acquire a SARS-CoV-2 infection, and water polo swimmers were most likely (70). Most open-water swimmers train on their own with less contact with others, and many train in ocean settings or saltwater pools, which may kill viruses. The use of common locker rooms increases the possibility of the transmission of viral infections. Instead of a high demand for endurance, some sports like climbing, gymnastics, and martial arts have a high resistance demand. In sports such as basketball, rugby, and swimming, on the other hand, endurance and resistance components are combined.

Laboratory confirmation of viral ARI is important. It has the potential for the identification and control of early outbreaks. An influenza epidemic may coincide with sports events, during which diagnosing influenza is crucial, as it can be treated and prevented with antivirals (54, 74). Additionally, an etiologic diagnosis is of importance for isolating infected athletes during competitions and training camps (77). Understanding the clinical characteristics and symptomatology of different respiratory viral infections in athletes can help address challenges related to the identification of ARIs. The occurrence and clinical significance of asymptomatic infections in athletes are unclear. There is only 1 study that has investigated the occurrence of asymptomatic respiratory viral infections in athletes. It reported that 8% of 26 athletes had an asymptomatic infection caused by the rhinovirus during a 2-week winter sports competition (136).

Table 2. Characteristics of studies included in the meta-analysis. ARI = acute respiratory illness.

Source	Country	Duration of study, d	Study desing	ARI definition	Symptom monitoring	Athletes				Controls				Controls	
						N	Sport	Mean (SD) age, y	Sex, No.	N	Sport	Mean (SD) age, y	Sex, No.	Athletes	Controls
Heir and Larsen, 1995	Norway	365	Prospective	2 or more local symptoms occurred for 2 or more days, or a single local symptom (excluding sneezing) lasted for 3 or more days	The subjects recorded all symptoms of respiratory infections, and two-thirds of the cases were verified by physicians.	19	Cross-country skiing	range 19-21	Male, 19	22	Military service recruits	Age matched	Male, 22	116	90
Chester et al, 2003	United Kingdom	365	Retrospective cohort study	colds, flu, sinusitis, coughs or sore throats	Retrospective questionnaire	199	Track and field	<20 yrs n=41 ≥20 <40 yrs n=140 ≥40 yrs n=18	Female, 72; male, 127	195	Largely university students	<20 yrs n=33 ≥20 <40 yrs n=163 ≥40 yrs n=6	Female, 128; male, 74	496,5	437,5
Fahlman and Engels, 2005	United States	365 (8 time points)	Prospective cohort	the infection lasted 3 or more days, and all 3 symptoms - cough, runny nose, and nasal congestion - were present througout the entire duration	A weekly log	75	Football	20.5 (1.5)	Male, 75	25	University students	20.5 (1.6)	Male, 25	174	19
Broadbent, 2011	Australia	365	Prospective cohort	Symptoms lasting for 3 days or more	A daily illness diary	15	Triathlon	30 (5)	N/A	12	Untrained men (no aerobic or resistance training or participation in recreational sports)	30 (6)	Male, 12	2	7
Umarov et al, 2018	Uzbekistan	365	Retrospective	N/A	N/A	40	Wrestling	range 19-24	Male, 40	60	healthy individuals of the same sex and age who were residents of the same country	Age matched	Male, 60	170	58,5
Umarov et al, 2019	Uzbekistan	365	Retrospective	Mild course: Presence of several symptoms of acute URTI, with no complications or symptom exacerbations	A self-reported questionnaire was completed in February and August	40	Swimmimg	range 19-24	Female, 40	30	healthy individuals of the same sex and age who were residents of the same country	Age matched	Female, 30	160	45,5

Table 3. Characteristics of uncontrolled studies with a duration of 12 months or longer. ARI = acute respiratory illness.

Source	Country	Duration of study	Study design	ARI/illness definition	Symptom monitoring	Athletes				No. of ARI	Mean number of ARIs per person per year
						N	Mean (SD) age, y	Sex, No.	Sport		
Clancy et al, 2006	Australia	12 months	Retrospective	N/A	Self-referral to a medical sports clinic due to fatigue, recurrent sore throats, and impaired performance	27	range 16.7-40.2	Female, 10; male, 17	N/A	63	2.3
Belli et al, 2010	Italy	29 months	Prospective	Any non-injury related medical condition requiring medication or treatment	N/A	35	37 (7)	Male, 35	Sailing	79	0.8
Hellard et al, 2011	France	24 months	Prospective	Signs or symptoms for >48 h, required medication, and missed at least one training session as a result of illness	Weekly by the two same physicians	18	range 19-30	Female, 8; male, 10	Swimming	109	3.7
Zehsaz et al, 2014	Iran	12 months	Retrospective	N/A	Questionnaire and interview	100	range 18-35	Male, 100	Predominantly endurance-based activities such as running, cycling, swimming, triathlon, and other sports	197	2.0
Svendsen et al, 2016	Norway	On average, 44 months per athlete	Retrospective cohort	One or more symptoms indicative of respiratory tract infection on two or more consecutive days, or when symptoms were severe enough that training was completely discontinued on at least 1 day	Symptoms were recorded in spreadsheet training diaries	37	18-34	Female, 17; male, 22	Cross-country skiing	410	3.0
Dumontier et al, 2020	Belgium	13 months	Prospective	For each symptom, the number of days was multiplied by the severity score (1-3) and then summed to provide the weekly upper respiratory tract symptoms score. A score of ≥ 12 was indicative of an upper respiratory tract symptoms episode	Weekly questionnaire	18	16.4 (3.4)	Female, 18	Gymnastics	33	1.7
Jeffries et al, 2020	Australia	12 months	Prospective	Upper respiratory signs and symptoms for ≥48 hours	the Wisconsin Upper Respiratory Tract Infection Survey	16	26.1 (5.1)	Female, 9; male, 7	Contemporary dance	134	8.4
Crunkhorn et al, 2022	Australia	12 months	Prospective	A complaint or disorder not related to injury	By doctors and physiotherapists	92	N/A	Female, 34; male, 58	Sailing	22	0.2

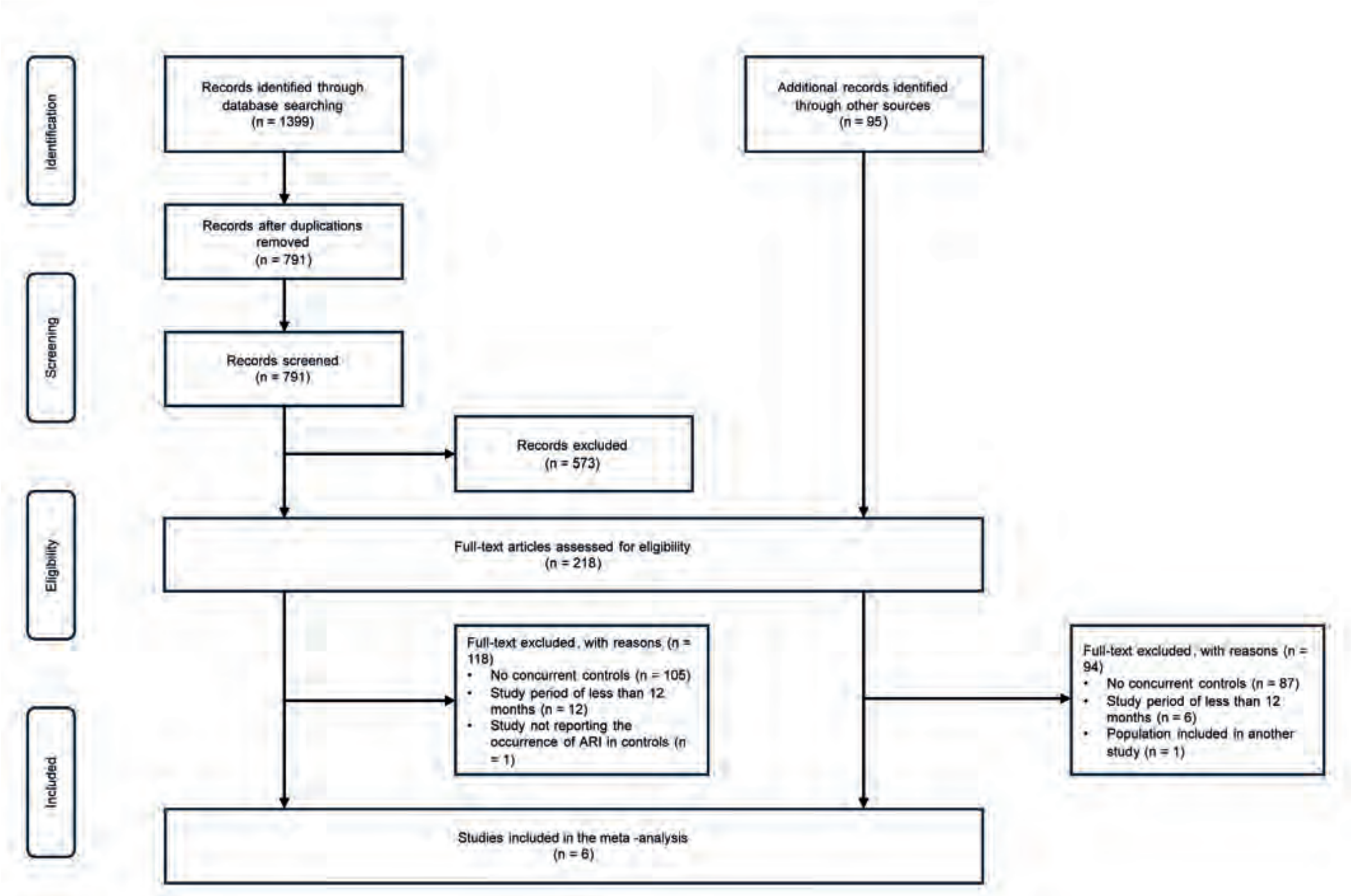

Figure 1. Flowchart of the study selection process. ARI = acute respiratory illness.

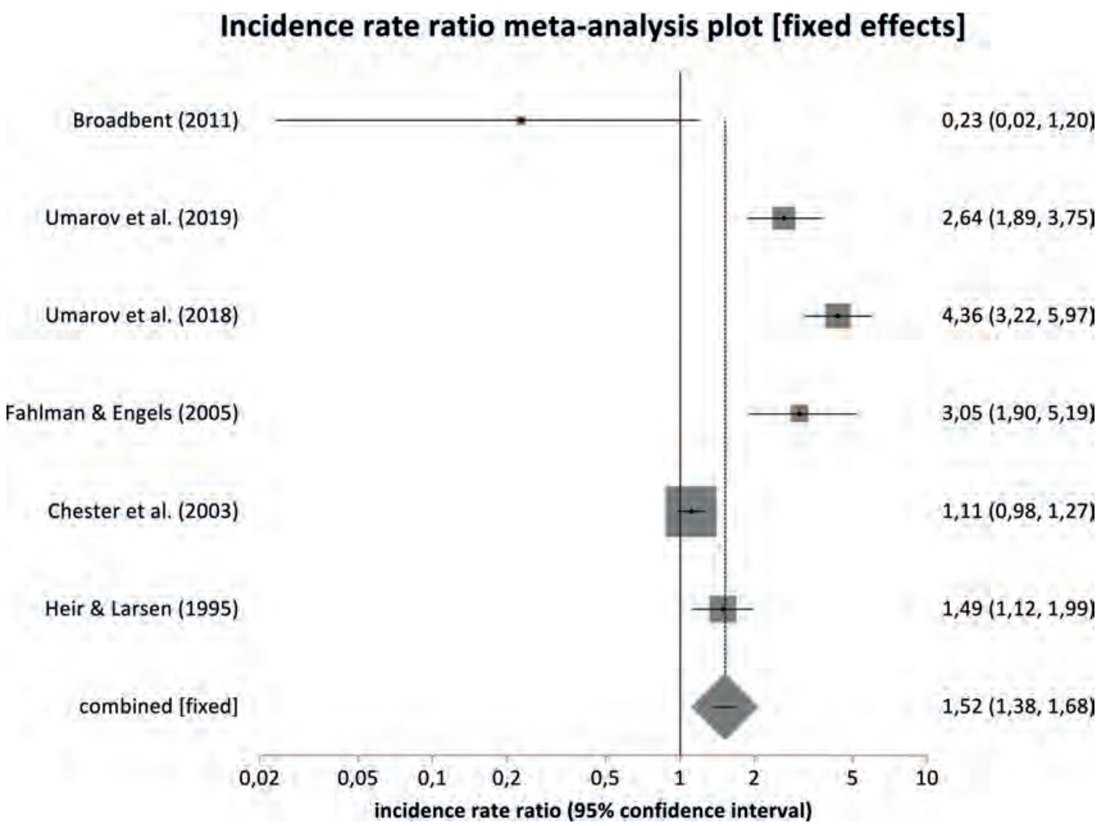

Figure 2. Pooled incidence rate ratios with 95% confidence intervals of the occurrence of ARI in athletes.

CONCLUSION

In this meta-analysis, the occurrence of ARI was significantly higher in athletes than in non-athlete controls. Most studies on the occurrence of ARIs in athletes are of low quality, and may potentially produce inaccurate assessments of the rate of ARIs. Future prospective controlled studies with a minimum duration of 12 months, with weekly monitoring and viral diagnostics, are highly needed. These kinds of studies are, however, economically and organizationally very demanding.

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AUTHORS' CONTRIBUTIONS

WG participated in the design of the study, carried out the literature search, data extraction, and analysis, and drafted the manuscript. MU confirmed the extracted data, supervised statistical analyses, and provided suggestions and revisions to the original draft. OR conceived the idea of the study, participated in the analyses, and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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