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Incidence of acute respiratory illnesses in athletes: a systematic review and meta-analysis by a subgroup of the IOC consensus on 'acute respiratory illness in the athlete'

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ABSTRACT

Objective To determine the incidence of acute respiratory illness (ARill) in athletes and by method of diagnosis, anatomical classification, ages, levels of performance and seasons.

Design Systematic review and meta-analysis.

Data sources Electronic databases: PubMed-Medline, EbscoHost and Web of Science.

Eligibility criteria Original research articles published between January 1990 and July 2020 in English reporting the incidence of ARill in athletes, at any level of performance (elite/non-elite), aged 15–65 years.

Results Across all 124 studies (n=1 28 360 athletes), the incidence of ARill, estimated by dividing the number of cases by the total number of athlete days, was 4.7 (95% CI 3.9 to 5.7) per 1000 athlete days. In studies reporting acute respiratory infections (ARinf; suspected and confirmed) the incidence was 4.9 (95% CI 4.0 to 6.0), which was similar in studies reporting undiagnosed ARill (3.7; 95% CI 2.1 to 6.7). Incidences of 5.9 (95% CI 4.8 to 7.2) and 2.8 (95% CI 1.8 to 4.5) were found for studies reporting upper ARinf and general ARinf (upper or lower), respectively. The incidence of ARinf was similar across the different methods to diagnose ARinf. A higher incidence of ARinf was found in non-elite (8.7; 95% CI 6.1 to 12.5) vs elite athletes (4.2; 95% CI 3.3 to 5.3).

Summary/conclusions These findings suggest: (1) the incidence of ARill equates to approximately 4.7 per athlete per year; (2) the incidence of upper ARinf was significantly higher than general (upper/lower) ARinf; (3) elite athletes have a lower incidence of ARinf than non-elite athletes; (4) if pathogen identification is not available, physicians can confidently use validated questionnaires and checklists to screen athletes for suspected ARinf. For future studies, we recommend that a clear diagnosis of ARill is reported.

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INTRODUCTION

A significant proportion of all medical consultations (~50%) at international single sport[1–8] and multisport events such as the Olympic,[9–13] Paralympic[14–16] and Youth Olympic Games[17 18] are due to acute illness in athletes, of which the respiratory system is consistently the most common organ system affected.[3 6 7 10 11 19 20] Acute respiratory illness (ARill) was the most common medical condition affecting athletes at both Summer and Winter Olympic and Paralympic Games,[11 13 20 21] as well as other major events and tournaments.[22 23] ARill in athletes can be broadly classified by an anatomical classification of ARill (predominantly affecting the upper or lower airways), and a pathological classification (non-infective ARill or acute respiratory infections (ARinf)). An athlete can present with a variety of symptoms of ARill, including upper ARill symptoms (blocked nose, runny nose, sore throat, swollen glands), lower ARill symptoms (cough, wheeze, chest pain) and in some cases ARill can be associated with systemic symptoms (fever, general fatigue and myalgia). While some symptoms indicate that the ARill is more likely to be due to ARinf (sore throat, swollen cervical lymph, fever) there is considerable overlap in the clinical presentation of non-infective ARill and ARinf. In most studies to date on ARill in athletes, the diagnosis was based on history and clinical assessment without laboratory confirmation of an infection, or the identification of a specific pathogen. Therefore, in the published literature on ARill in athletes it is not always possible to determine if athletes had a non-infective ARill or a suspected/confirmed ARinf. In these studies, the ARill was reported without a specific diagnosis because the ARill could not be attributed to an infective or non-infective cause.

ARill may occur at various stages of training and competition including the precompetition period (preparation training period), competition period (intracompetition) and/or postcompetition recovery period.[24 25] ARill, in particular ARinf and can interrupt training and impact competition performance.[26 27] While most ARill may be easily managed by the team physician, some may have systemic sequalae which can constitute a serious threat to the health of the athlete. Thus, it is important for clinicians to know how many ARill can be expected to occur in their team, over what period and which athletes may be more susceptible to ARill. Different factors may influence susceptibility to ARill in athletes, such as intensity and duration of exercise,[28] participating in events and/or tournaments,[21] gender[29] and season of training and competition.[30] Spence *et al*[31] observed substantially

higher incidence rates of ARill in elite athletes compared with recreationally competitive athletes.

Numerous studies have investigated the incidence of ARill in athletes participating in different sports, including runners,[23 32 33] cyclists,[34] cross-country skiers,[35] swimmers,[36–38] rowers[39] and in athletes from other team sports such as rugby players[40] and wheelchair athletes.[41] Previous studies investigated ARill in different levels of performance, different types of ARill (infective vs non-infective) and using different types of diagnostic methodologies.[42] To our knowledge, no previously conducted epidemiological studies have convincingly determined the overall incidence rates of ARill in athletes, nor has it been determined whether the incidence of ARill is affected by level of performance or age of the athlete. Thus, the primary aim of this systematic review and meta-analysis was to determine overall the incidence of ARill, including subgroups categorised by pathology (ARinf vs undiagnosed ARill), predominant anatomical region affected (upper vs lower respiratory tract or general), different levels of athletic performance (elite vs non-elite athletes), age groups (15–35 years vs >35 years) and season (summer vs winter).

METHODS

Protocol and registration

A protocol was developed according to the guidelines outlined in the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[43]

Study selection and eligibility criteria

Eligibility criteria were established and agreed on by all authors based on the concepts of population, intervention/indicator, comparator/control and outcome. Studies that met the following inclusion criteria were considered eligible to be included in this systematic review and meta-analysis:

1. Participants, both male and female, aged 15–65 years, who are athletes at any level (recreational to elite) engaged in training.
2. Participants had self-reported, physician or laboratory diagnosed ARill.
3. Studies reported ARill during events, tournaments, multistages of events and those that are reported directly after an event.
4. Studies reported the number of ARill among the participants as well as documented the study period.
5. Journal article with full-text original prospective and/or retrospective studies published in English between 1 January 1990 and 31 July 2020.

Exclusion criteria were set as:

1. Studies conducted in animals or human cells expressed in rodents.
2. Conducted with a heterogeneous sample (ie, mixed sample of athletic and non-athletic populations) without reporting individual group findings separately.
3. Studies available as an abstract only (ie, conference presentations), qualitative or case series, discussion paper, commentary or literature review.
4. Studies not available in English.
5. Studies specifically investigating only known non-infective ARill, including asthma, airway allergies or cold air injury (studies reporting ARill that could include both ARinf and non-infective causes were included and categorised as undiagnosed ARill).

Search strategy

PubMed-Medline, EbscoHost and Web of Science (core collection) databases were searched for published articles from 1 January 1990 to 31 July 2020. Medical subject heading (MeSH) terms included a combination of search terms relating to (acute respiratory illness AND athlet* AND prevalence/incidence) and relevant exclusions (for full search string for each database, see online supplemental file S1). Studies including the terms 'allergy' and 'asthma' were excluded from the search, as these terms are covered in separate comprehensive assessments of asthma and allergy in athletes (IOC consensus statement subgroups; under review). A secondary search of the reference lists of included articles, and an additional search in Google Scholar were conducted, as well as addition of other articles identified by the authors, that were not captured in the original search. The results of these searches were combined, and duplicate articles removed (figure 1).

Article screening and selection were performed using the online platform Central Access Database for IMpact Assessment (CADIMA).[44] Articles were initially screened by title and abstract independently by two reviewers (LK and MB) using the selected inclusion/exclusion criteria. After this initial screening, the full texts of the articles were retrieved, and a second screening was undertaken by independent reviewers (MM, MG, LK and ME). Any conflicts were resolved through discussion and consensus was achieved between the reviewers.

Data extraction

The following data were extracted from the included articles by two independent reviewers (LK and MB) and checked by another author (ME): Participants (number, age, gender), study design, method used to diagnose illness, illness classification (pathological and anatomical), level of performance (professional/elite or amateur/trained/competitive/recreational), sport type, length of surveillance period and the number of ARill.

Definitions and classification of subgroups of ARill

We recognise that the methods used to diagnose an ARill, and specifically an ARinf can vary and include symptoms only, additional findings on clinical examination, and the use of special investigations to identify a specific pathogen. The methods used to diagnose ARill in each study were classified as follows: (1) self-reported symptoms of ARill only and (2) self-reported symptoms but with an algorithm indicative that was validated for ARinf. The validated questionnaires that were used included the Wisconsin Upper Respiratory Symptom Survey-21[45] or the Jackson Cold Scale[46] or other questionnaires in which the severity of the symptoms were scored to provide a quantitative assessment according to Fricker *et al*[28] and Matthews *et al* (AIS Symptom log),[47] (3) self-reported symptoms of an ARinf reviewed by a physician, but without clinical or laboratory evaluation, (4) clinical diagnosis of an ARinf by a physician, based on history and clinical examination, (5) diagnosis of ARinf by a physician that was confirmed by laboratory investigation to identify a specific pathogen as follows: PCR testing on specimens, culture of an organism from specimens, or serology (eg, rise in antibody titres). Data were extracted for each study, and this was agreed on by consensus (WD, MM, MG, JF, KM and NS). Once studies were classified by the five methods of diagnosis, all ARill studies were included in one of the following main and subgroups of ARill, based on a pathological classification (table 1).

We acknowledge that ARill, including ARinf, frequently presents with both upper and lower respiratory tract symptoms/signs and it is not always possible to clearly distinguish between these main anatomical regions when classifying ARill. A limitation of this anatomical classification is that several pathogens that

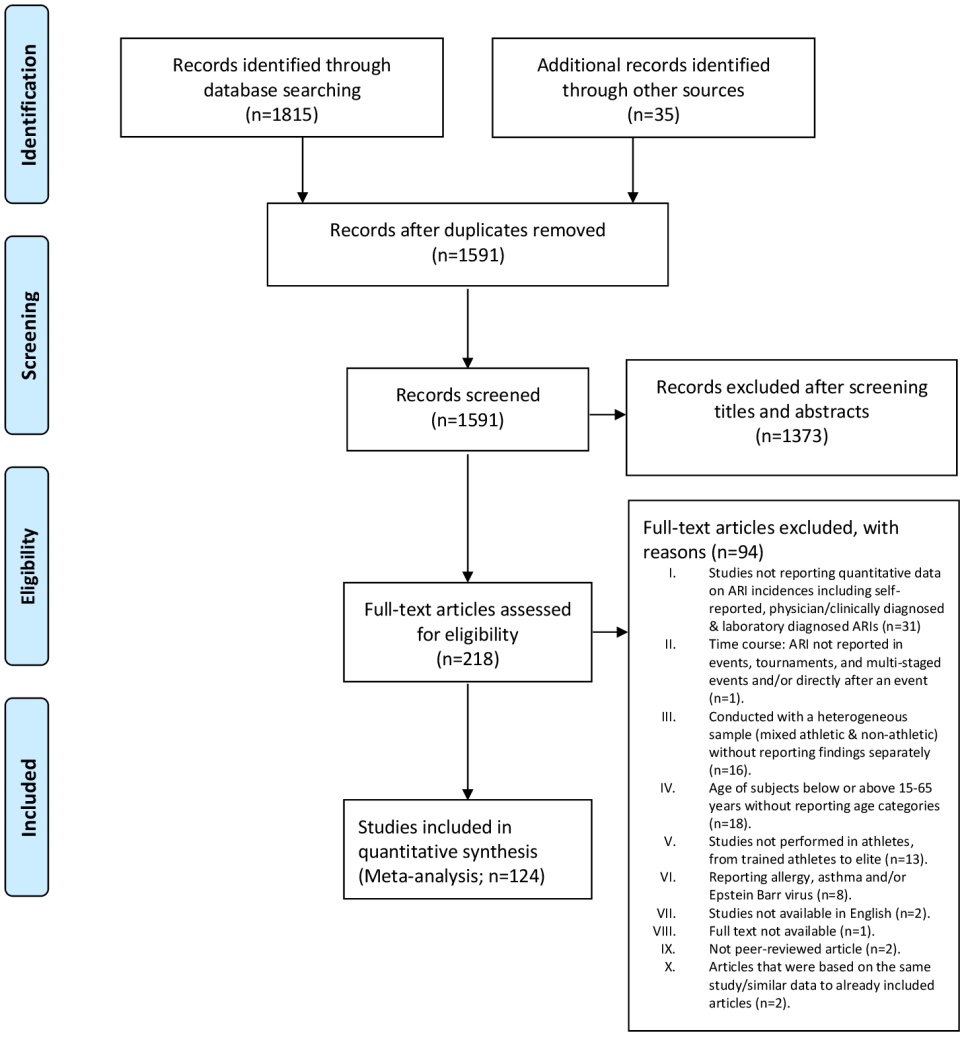

Figure 1 PRISMA flow diagram visualising the selection process of identified, screened and included articles following assessment of the eligibility criteria. ARI, acute respiratory illness; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

cause predominantly upper ARinf can, in some cases, present with lower respiratory and/or systemic symptoms. However, from a clinical/pragmatic point of view, and the fact that a clear distinction is made in many studies, we felt that it is relevant to include this anatomical classification in the review. Upper ARinf (suspected or confirmed) is the most common acute illness in athletes. We classified all studies of into the following subgroups, based on the predominant anatomical region affected:

- Upper (ARill or ARinf): Studies where the predominant symptoms, signs, or confirmed pathology was clearly related

Table 1 Pathological classification (main and subgroups) of acute respiratory illness (ARill) and infections (ARinf) by diagnostic method

Pathological classification			
Main group	**Subgroup**	**Methods to diagnose ARill**	**Description**
Undiagnosed ARill		► Self-reported symptoms of ARill only ► Self-reported symptoms combined with an algorithm at least partially validated for ARill ► Self-reported symptoms of an ARill reviewed by a physician, but without clinical or laboratory evaluation ► Clinical diagnosis of an ARill by a physician, based on history and clinical examination	► General symptoms of an ARill where the pathology could not be attributed specifically to an infection ► ARill studies could include illnesses that are due to either infective or non-infective causes but were not specified in the study design
ARinf	Suspected ARinf	► Self-reported symptoms combined with an algorithm that has been validated for ARinf ► Self-reported symptoms of an ARinf reviewed by a physician, but without clinical or laboratory evaluation ► Clinical diagnosis of an ARinf by a physician, based on history and clinical examination	► General symptoms and/or physical signs suggestive of an ARinf, but where the specific pathology of an infection was not confirmed ► The validated questionnaires that were used included the Wisconsin Upper Respiratory Symptom Survey-21[45] or the Jackson Cold Scale[46] or other questionnaires in which the severity of the symptoms were scored to provide a quantitative assessment (AIS Symptom log).[11]
	Confirmed ARinf	► Clinical diagnosis of ARinf by a physician that was confirmed by laboratory investigation to identify a specific pathogen using PCR testing on specimen(s), culture of an organism from specimen(s) or serology (eg, rise in antibody titres)	► In some studies, the identified pathogen was associated with a viral outbreak in a sporting team. The incidence rates in these studies may not reflect the rates of ARinf in general studies monitoring for ARinf in athletes.

to the upper respiratory tract (ie, above the larynx), or if the study specifically referred to athletes with upper respiratory illness. A few studies referred to clinical syndromes of ARinf using non-specific terms such as 'influenza', 'influenza symptoms', 'common cold', 'symptoms suggestive of influenza', 'influenza symptoms' or 'influenza like'. Studies referring to these clinical syndromes were also included in this broad anatomical classification because they are caused by pathogens that all present with predominantly upper respiratory tract symptoms.[48–51] Notably, this includes influenza viruses, which also predominantly present with upper respiratory tract symptoms[52] and are listed as a cause of upper respiratory tract infections.[48–50]

- Lower (ARill or ARinf): Studies where the predominant symptoms were below the larynx (including chest symptoms that is, cough, chest pain), or if the diagnosis specifically referred to athlete with lower respiratory illness (tracheal, bronchial or lung pathology for example, pneumonia).
- General (upper/lower) (ARill or ARinf): Studies where it was not possible from the methods or results to distinguish between predominantly upper or lower respiratory tract ARill or ARinf, and could therefore include upper, lower or both.

Performance level

The athlete's level of performance was categorised as follows: (1) Professional athletes (member of a professional league), (2) elite (international competition), (3) amateur athletes (largely or entirely engaged in sports without remuneration,[53] (4) competitive (collegiate or regional) athletes, (5) trained athletes (undertaking daily exercise engaged in similar volumes of training as competitive athletes) and (6) recreational athletes (physically active but who does not train for competition at the same level of intensity and focus as competitive athlete.[54] For subgroup analyses, the professional and elite athletes were combined and referred to as 'elite' athletes. There were five studies where athletes were classified as recreational, and these were included in the analysis with the combined amateur, competitive and trained athletes. This subgroup was referred to as 'non-elite' athletes.

Age groups

The age groups of athletes that were included in the studies were categorised as: (1) 15–35 years or (2) older than 35 years. The age threshold of 35 years was chosen based on the International Masters categorisation.[55]

Quality assessment and risk of bias

A modified Downs-and-Black tool was used to determine the quality of the articles.[56] The tool consisted of items as follow: reporting, external validity, internal validity (bias and selection bias). Each item was scored as 'yes' (score=1), 'no' (score=0) or 'undetermined' (score=0). Four reviewers (LK/ME/MM/MG) performed the independent quality assessment of the studies. The same reviewers determined the level of evidence using the 2009 Oxford Centre for Evidence Based Medicine (OCEBM).[57] The studies fell into two main categories: (1) Observational studies of symptoms of ARill in populations; (2) Intervention studies where the incidences of ARill were determined in response to an intervention. The observational studies were graded using the OCEBM 'Symptom Prevalence Study' levels of evidence, and the Intervention studies were graded using the 'Therapy/Prevention Studies' levels of evidence for randomised controlled trials.

Data analysis

The estimated pooled incidence of ARill and ARinf (determined by dividing the number of new cases of ARill and ARinf observed, by the total number of athlete days, per 1000 athlete days) were estimated using the DerSimonian Laird Random effects model[58] to account for the heterogeneity in the cohorts (eg, differences in diagnostic technique, performance level of athlete) and weighting of studies. The estimations for ARill and ARinf were based on the number of studies in the individual categories, hence they have different denominators to calculate the IR. Heterogeneity was measured using I^2 and Cochran's Q statistics.[59] Forest plots were produced to illustrate the results. All meta-analyses were conducted by using MetaXL.[60] A significance level of 0.05 was accepted, and all statistical tests were two tailed. Differences between subgroups were determined by comparing 95% CIs.

Analyses of the following subcategories were also performed (only subcategories with more than three articles) based on the following: (A) methods to diagnose ARill, (B) pathological classification and (C) the anatomical classification (table 1).

A further analysis was done based on subgroups of ARinf, including studies that could confirm an infection (ARinf confirmed) and studies that used various methods to diagnose an infection (ARinf suspected) as follows:

- The athlete's performance level: Elite (including elite and professional athletes) or non-elite (including trained, amateur, competitive and recreational athletes).
- Age group: 15–35 years or older than 35 years.
- Season: Summer or Winter.
- Quality of the study, based on modified Downs-and-Black tool: Excellent, good, fair or poor.

RESULTS

Study selection

A total of 1583 studies were identified in the databases and additional sources for screening. Figure 1 summarises the study selection process and reasons for excluding studies. The full texts of 218 articles were assessed for eligibility, 94 were excluded and 124 were used for data extraction. All articles that passed the inclusion criteria (n=124) were included in the meta-analysis for the pooled incidence of ARill, as well as for the illness diagnosis sub analysis. For the remainder of the subanalyses, only studies that investigated ARinf ('Infective confirmed' or 'Infective suspected') in the anatomical classification of 'upper' or 'general (upper/lower)' were included (n=107). ARill in the 'undiagnosed' subcategory (n=17) were excluded from this subanalysis.

Level of evidence and quality assessment

Of the total studies assessed, 47 studies (38%) were rated using the 2009 OCEBM scale[57] as 1b level of evidence, 21 studies (17%) were rated as 2b level of evidence and 56 studies (45%) were rated as 3b level of evidence (online supplemental table 2).

The results of the quality assessment, using the modified Downs and Black scores, are presented in online supplemental table 3. The majority of studies were rated either excellent or good (n=104; 89%). The studies that were rated as fair (n=5; 4%) or poor (n=9; 7%) were mostly based on failing to meet the internal and external validity requirements, not reporting actual probability values, not describing characteristics of participants lost to follow-up, not providing estimates of random variability in the data for the main outcomes and not describing findings in the main outcomes. Studies rated as 'poor' were not excluded from analyses.

Table 2 Number of studies and % (of all studies) by pathological and anatomical classification and method of diagnosis of ARill and ARinf

Pathological classification		Anatomical classification			All	
Main group	Subgroups	Upper	Lower	General (upper/lower)	Total	Study references
All ARill		91 (73%)	1 (1%)	32 (26%)	124	
Undiagnosed ARill	All undiagnosed	9 (7%)	–	8 (6%)	17 (14%)	11 14 18–21 23 40 75–83
	Self-reported symptoms only	7 (6%)	–	–	7 (6%)	23 40 77–79 81 82
	Self-reported symptoms with an algorithm	1 (1%)	–	–	1 (1%)	76
	Symptoms reviewed by a physician, but without clinical or laboratory evaluation	1 (1%)	–	–	1 (1%)	75
	Clinical diagnosis by a physician, based on history and examination	–	–	8 (6%)	8 (6%)	11 14 18–21 80 83
Infective (ARinf)	All infective	82 (66%)	1 (1%)	24 (19%)	107 (86%)	
	Suspected infective	79 (64%)	1 (1%)	24 (19%)	104 (84%)	1–6 8–10 12 13 16 17 22 28 30–33 35–38 41 71 84–161
	Self-reported symptoms with an algorithm	46 (37%)	1 (1%)	4 (3%)	51 (41%)	22 31–33 35 37 41 76 85 87 89 91 93 95 97 100 102 104 106–111 117–123 125 126 128 134 136–140 142 144 147 148 151 152 154–156 161 162
	Symptoms reviewed by a physician, but without clinical or laboratory evaluation	9 (7%)	–	1 (1%)	10 (8%)	90 92 94 105 124 129 135 159 160 163
	Clinical diagnosis by a physician, based on history and examination	24 (19%)	–	19 (15%)	43 (35%)	1–10 12 13 16 17 28 30 36 38 84 86 88 96 98 99 101 103 112 114–116 130–133 141 143 145 146 150 153 157 158 164
	Confirmed infective Diagnosis by a physician and confirmed by laboratory investigation to identify a specific pathogen	3 (2%)	–	–	3 (2%)	63 64 66

ARill, acute respiratory illness; ARinf, acute respiratory infections.

Study characteristics

The data extracted from the studies included in the present analysis are presented in online supplemental table 2A. The 124 studies had a total of 128360 (study range: 4–53 906) participants, including 74 860 males, 53 500 females and 9862 athletes with non-specified gender. Studies were conducted across 41 different sports, of which the majority included athletes participating in swimming (12 studies), endurance running (13 studies), rugby (9 studies), soccer (8 studies), athletics (7 studies) and studies who included athletes practicing mixed endurance sports, such as runners, cyclists, triathletes or swimmers (10 studies), mixed Winter Olympic (7 studies) and Paralympic sports (5 studies), and mixed Summer Olympic (5 studies) and Paralympic sports (3 studies).

Number of studies by pathological and anatomical classification of ARill

The number of studies by pathological and anatomical classification, as well as the specific study references, are presented in table 2. Of all studies included in the meta-analysis, the majority (73%) reported on upper ARill. In addition, 86% of all studies investigated ARinf, of which most studies reported on upper ARinf (82/107=77%). With regards to the methods used to diagnose ARinf, most of the studies report suspected ARinf (104/107=97%), of which the majority used either self-reported symptoms with an algorithm (51/104=49%) or clinical diagnosis by a physician, based on history and examination (41/104=39%). In only three studies (3%) was ARinf confirmed by means of special investigations described above.

Incidence of any ARill

Across all studies, the estimated pooled overall incidence (per 1000 athlete days) of any ARill was 4.7 (95% CI 3.9 to 5.7).

Incidence of undiagnosed ARill

Across the studies the estimated pooled incidence of undiagnosed ARill (n=17) was 3.7 (95% CI 2.1 to 6.7). In all these studies, the specific cause of the ARill could not be determined and could include illnesses that are due to either infective or non-infective causes. In 8/17 (47%) of these studies the ARill was assessed by a physician (history and examination) and in 7/17 (41%) the ARill was classified using self-reported symptoms only. The sample size in this subgroup (n=17) was too small to conduct further analysis by level of performance, age group and season.

Incidence of ARinf

In studies reporting ARinf the incidence (per 1000 athlete days; 95% CIs) of ARinf by pathological and anatomical classification and by method of diagnosis is presented in table 3 (Forest plots are presented in online supplemental file 4).

Incidence of ARinf by pathological and anatomical classification and by method of diagnosis

Across all studies reporting ARinf, an incidence of 4.9 (95% CI 4.0 to 6.0) was found. For studies including upper ARinf, an incidence of 5.9 (95% CI 4.8 to 7.2) was found, while for studies that reported on general ARinf (upper or lower) the incidence was 2.8 (95% CI 1.8 to 4.5).

Subgroup analysis of suspected ARinf, which included most studies (79 studies), showed an incidence of 5.7 (95% CI 4.6 to 6.9). The three studies of confirmed ARinf showed an incidence of 18 (95% CI 5.7 to 56.8). The incidence was 2.8 (95% CI 2.1 to 3.8) if the diagnosis was made by a physician based on history and clinical examination only; and if the diagnosis was made based on self-reported symptoms utilising a checklist and algorithms, the incidence was 7.4 (95% CI 5.9 to 9.4). Furthermore, an incidence of 5.1 (95% CI 2.6 to 10.2) was found if the

Table 3 The incidence (per 1000 athlete days; 95% CI) of acute respiratory infection (ARinf) by pathological and anatomical classification and by method of diagnosis

Pathological classification		Anatomical classification		
Main group	Subgroups	Upper ARinf	General ARinf (upper/lower)	All ARinf*
ARinf	All infective	5.9 (4.8–7.2)	2.8 (1.8–4.5)	4.9 (4.0–6.0)
	Suspected infective	5.7 (4.6–6.9)	2.8 (1.8–4.5)	4.7 (3.9–5.8)
	Self-reported symptoms with an algorithm	7.6 (5.7–10)	7.9 (3.6–17.2)	7.4 (5.9–9.4)
	Symptoms reviewed by a physician, but without clinical or laboratory evaluation	5.3 (2.5–11.3)	†	5.1 (2.6–10.2)
	Clinical diagnosis by a physician, based on history and examination	3.4 (2.5–4.6)	2.2 (1.3–3.7)	2.8 (2.1–3.8)
	Confirmed infective Diagnosis by a physician and confirmed by laboratory investigation to identify a specific pathogen	18.0 (5.7–56.8)	–	18.0 (5.7–56.8)

*Including all studies reporting on ARinf, including upper, lower and general (upper/lower) ARinf.
†Numbers of studies too small to calculate.

diagnosis was made using self-reported symptoms reviewed by a physician, yet without clinical examination.

Incidence of ARinf in subgroups by level of performance, age group and season

The incidence of ARinf for the further subgroup analyses are presented in table 4. A higher incidence of ARinf was found in non-elite athletes (8.7; 95% CI 6.1 to 12.5) than in elite athletes (4.2; 95% CI 3.3 to 5.3). The incidence of ARinf was similar in older athletes (>35 years) (9.1; 95% CI 5.2 to 16.0) and younger athletes (5.9; 95% CI 4.3 to 7.9). Across the studies that were conducted during summer, the incidence of ARinf was similar (3.5; 95% CI 2.5 to 4.9) to that during winter (5.8; 95% CI 4.6 to 7.8).

Incidence of ARinf by quality assessment of studies

The incidence of ARinf was similar by quality assessment of studies as follows: excellent (4.9; 95% CI 3.9 to 6.3), good (6.3; 95% CI 4.7 to 8.6), fair (2.1; 95% CI 0.8 to 5.6) and poor (5.2; 95% CI 0.8 to 35.3).

DISCUSSION

The aim of this systematic review and meta-analysis was to determine the overall incidence of ARill, including subgroups categorised by pathology (undiagnosed ARill vs ARinf and subgroups of ARinf), predominant anatomical region affected (upper vs unclassified upper/lower), different levels of athletic performance, age groups, season and quality of study. We also sought to determine outcomes in subgroups of ARill in athletes based on the method that was used for the diagnosis of ARill.

Incidence of ARill in athletes

The first main observation was that the estimated overall pooled incidence (per 1000 athlete days) of ARill in athletes was 4.7 (95% CI 3.9 to 5.7) and there was no significant difference in the incidence of undiagnosed ARill (3.7; 95% CI 2.1 to 6.7) vs all ARinf (suspected and confirmed) (4.9; 95% CI 4.0 to 6.0). The reasons why the incidence of undiagnosed ARill is similar to that of ARinf is likely because most ARill in athletes are due to infection and that non-infective ARill (eg, allergic rhinitis) is a predisposing factor for ARinf.[61] Another explanation could be that studies that specifically investigated only known acute

Table 4 The incidence (per 1000 athlete days; 95% CI) of ARinf by age group, performance level, season and quality of study subcategories

	Subcategory		
Category	Incidence rate (95% CI)	Total studies	Study references
Age group			
15–35 years	5.9 (4.3 to 7.9)	51	2 4 17 22 28 30 31 33 35–38 63 64 87 89 90 92 94 97 98 103 105 107 115 118 119 121–125 128 129 132 134 138–141 143 146 147 150 152 155 156 159 160 162 163
>35 years	9.2 (4.8 to 17.6)	5	111 120 137 151 154
Level of performance			
Elite	4.2 (3.3 to 5.3)	53	1 3 4 6 8–10 13 16 22 28 30 38 66 71 84 86–90 92 93 99 101 105 114–116 119 122 124 125 128–136 141 144 145 150 154 157 158 160 164
Non-elite	8.7 (6.1 to 12.5)	19	33 91 94 95 97 98 100 102 103 110 113 117 138 140 144 151 155 159 162
Season			
Summer	3.5 (2.5 to 4.9)	28	4 8 10 12 13 17 28 64 66 88 98 101 107 114 116 119–121 129 131 140 143 146–148 150 155 158
Winter	5.8 (4.6 to 7.8)	29	1 2 6 9 16 31–33 71 84 86 89 95 97 99 102 111–113 127 130 135–137 145 153 157 161
Quality of study			
Excellent	4.9 (3.9 to 6.3)	71	2 3 5 9 12 13 22 28–33 36–38 41 64 71 87 89–92 95 98 102 103 105 107 108 110 112 113 115–121 123 125 126 128–133 137 139 140 142–147 150 151 154 156 157 159 160 163 164
Good	6.3 (4.7 to 8.6)	23	8 16 35 63 66 84 85 88 93 97 100 101 104 111 114 122 134 135 141 148 155 158 162
Fair	2.1 (0.8 to 5.6)	9	6 86 94 99 124 136 138 153
Poor	5.2 (0.8 to 35.3)	4	4 96 109 152

ARinf, acute respiratory infections.

non-infective ARill, including acute asthma, allergies or cold air injury, were excluded. However, these reasons are speculative, and we encourage that a precise diagnosis of all ARill is reported in future studies.

Incidence of ARinf in subgroups by pathological classification

The incidence of suspected ARinf was not different by method of diagnosis. Earlier research showed that self-reported symptoms of ARill agree with physician-based diagnosis, suggesting that individuals are capable of adequately reporting symptoms.[45] The practical application of these data is that sport and exercise medicine (SEM) physicians can confidently use validated questionnaires and checklists to screen athletes for suspected ARinf.[42] These findings may have important considerations for choices around data collection methods in future large epidemiological studies. Research showed that patient-reported data can complement clinician-reported data to achieve more reliable measurements of clinical outcomes.[62]

Laboratory-based identification of a pathogen is the most accurate method for confirming the diagnosis of ARinf.[42] The results of this analysis showed an apparent high incidence of confirmed ARinf (18; 95% CI 5.7 to 56.8). These data must be interpreted with caution because they are based on only three studies in which only two studies report very high incidences of confirmed ARinf (as visible in the forest plots, presented in online supplemental file 4). In one of these studies, there was a Streptococcal outbreak in 23 athletes over 15 days (IR of 40.6/1000 athlete days).[63] In another study, seven clusters of different respiratory viral infections were recorded, with a 'common cold' in 44 athletes over 21 days, resulting in an IR of 26.7/1000 athlete days,[64] which could have been caused by different risk factors such as the competition, international air travel and time difference.[65] A large outbreak of infections from one pathogen in a small number of athletes is unusual and contrasts to the other study in this group.[66]

Pathogen identification is an important part of clinical practice[42] and for the SEM physician this will allow for identification of more pathogens causing more serious ARinf. More serious ARinf may be associated with multiorgan involvement, higher risk of serious medical complications during exercise, and prolonged return to play (eg, for COVID-19).[67] As a consequence of the COVID-19 pandemic, laboratory testing, such as PCR tests, might be more accessible, although we acknowledge that in some sports medicine settings laboratory testing may still not be feasible due to cost or inaccessibility. In these settings, our results confirm that a clinical diagnosis by a physician through history and physical examination, as well as use of self-reported symptoms using validated questionnaires or checklists or even symptom review by a physician without clinical or laboratory evaluation, can be used to diagnose ARinf.

Incidence of ARinf in subgroups by anatomical classification

For subgroups by anatomical classification, the incidence of upper ARinf was significantly higher than general (upper/lower) ARinf. This finding is not surprising and is in keeping with results from several studies reporting that upper ARinf is the most common non-injury related health problem in athletes and in the general primary care setting.[68] Lower ARinf seem to be very rare in athletes. The incidence of ARinf in athletes was 4.9 (95% CI 4.0 to 6.0), and for upper ARinf was 5.9 (95% CI 4.8 to 7.2). This equates to an incidence of approximately 1.8 ARinf per athlete per year. In the general adult population, the incidence of ARinf is approximately 2–3 per person per year,[69 70] yet it is unclear from the literature if the statistic in the general population is only upper ARinf or all ARinf. Thus, the annual incidence of ARinf in athletes appears similar or marginally lower than the general adult population. It is important to note that in most studies the incidence of ARinf in athletes has been reported over short observation periods (during a competition or in a season) and not over a 1-year period. These shorter observation periods are typically associated with the increased physical and emotional load associated with competition as well as international travel, all of which can increase the incidence of ARinf.[71 72] Therefore, the true annual incidence of ARinf in athletes might be even lower. Based on the findings of this review, if a team physician is looking after the health of 100 athletes over a competition that lasts 3 weeks, it was estimated that medical teams will have to manage approximately 10 acute respiratory tract infections.

Incidence of ARinf in subgroups by level of athlete performance, age groups, seasons and quality assessment of studies

The incidence of ARinf in studies in elite athletes was significantly lower (4.2; 95% CI 3.3 to 5.3) compared with non-elite athletes (8.7; 95% CI 6.1 to 12.5). Although a higher training load is a general risk factor or for ARill (J-shaped curve),[67 73] there are data to suggest that elite athletes, compared with non-elite athletes have a lower susceptibility to ARill (S-shaped curve).[67] A further explanation could be that elite athletes have more access to a team physician and preventative support from allied health professionals, while non-elite athletes are less likely to have access to such medical support teams. Significant differences with respect to age of athlete and seasonal variation were not observed in this meta-analysis.

Although, the incidence of ARinf varied in subgroups by the quality assessment of the studies, this was not significantly different. As most studies were rated as either excellent or good (88%), the quality of the studies did not have a major influence on the overall incidence for ARinf.

Strengths and limitations

To our knowledge, this is the first systematic review to determine the incidence of ARill in athletes. We registered the review with PROSPERO and followed a systematic approach using an online tool, CADIMA. Furthermore, we developed a classification system, based on methods to differentiate between ARill and ARinf, and performed our subgroup analyses using a pathological and anatomical classification. This was important to address heterogeneity across studies in definitions and nomenclature of ARill, upper ARinf, and undiagnosed ARill. We believe this approach provides a more comprehensive clinical picture to inform clinical assessment and practice. This review has clinical importance and relevance given that ARill are the most common illnesses affecting athletes.

There are a number of limitations. A first possible limitation is that we excluded specific studies where only non-infective ARill, such as asthma, airway allergies or cold air injury to the airways were reported. These conditions are an important cause of respiratory symptomatology in athletes, which can be confused with ARinf.[74] In our study, we grouped undiagnosed ARill as those where a study population with ARill could include infective or non-infective ARill. It is possible that some of these conditions might have been present in that group. It is for this reason that we analysed undiagnosed ARill as a specific subgroup and did not include these studies in the ARinf group. Therefore, a

strength of this meta-analysis was that, in the subgroup analyses we focused on ARinf, therefore removing other non-infective causes of airway symptomatology as best as possible. We did not perform further analyses of subgroups (by level of athlete performance, age groups, seasons and quality assessment of studies) of the undiagnosed ARill group because the sample size of these studies was too small. Although not a limitation, this resulted in most of the review and meta-analysis focusing on ARinf.

Second, this review considered research published only in the English language, such that relevant studies conducted in non-English language were not included. We also excluded qualitative studies, reviews, commentary and discussion as well as case studies, which can be a rich source of information regarding the prevalence and incidence of ARill. Nevertheless, the broad search strategy utilised in this review ensured a degree of confidence that, within the inclusion criteria for incidence and/or prevalence of ARill from original studies were identified and appraised.

Third, the number of participants used to calculate the overall incidence could be biased or skewed, due to the high number of elite (Olympic/Paralympic) athletes in some of the studies.

Fourth, the incidence of less or more severe ARill or ARinf could not be determined in this systematic review. In most studies, severity of ARill was not reported as there is no consistent definition of severity of ARill.

Fifth, there was also a high degree of heterogeneity between studies. This was evident, as the I^2 for all analyses was >90%, and therefore, the results should be interpreted with caution.

Finally, the number of studies included in some subgroup analyses was relatively small and this limits the interpretation of findings across subgroups. Specifically, the number of studies in which ARinf was confirmed by pathogen identification the subanalysis was small (n=3) compared with the number of studies where ARinf was suspected (based on history and clinical examination) (n=44).

Summary and clinical implications

This systematic review and meta-analysis demonstrated that the overall incidence of ARill among athletes was 4.7 per 1000 athlete days (95% CI 3.9 to 5.7). The overall incidence of ARinf (suspected and confirmed) was 4.9 (95% CI 4.0 to 6.0) and similar to the incidence of ARill in studies reporting undiagnosed ARill (3.7; 95% CI 2.1 to 6.7). The highest incidence, by anatomical classification, was for upper ARinf at 5.9 (95% CI 4.8 to 7.2), which translates to approximately 1.8 ARinf per athlete per year. The incidence of ARinf in studies in elite athletes was significantly lower (4.2; 95% CI 3.3 to 5.3) compared with non-elite athletes (8.7; 95% CI 6.1 to 12.5). In the other subgroup analyses, there was no difference in the incidence of ARinf in subgroups by methods to diagnose ARinf, age groups, seasons or quality assessment of studies. We recommend the diagnosis of ARinf be based on physician clinical assessment, but include laboratory confirmation of the pathogen, if indicated and possible. Pathogen confirmation is the most definitive diagnostic method.[42] In cases where laboratory testing is not feasible, we recommend using self-reported symptoms using validated questionnaires or checklists to diagnose ARinf. However, specific pathogen identification to refine the diagnosis of ARinf in athletes is likely to become more important in future. It is known that some pathogens that cause very mild ARinf with minimal risk of medical complications during exercise or interruption of training, while other pathogens (eg, SARS-CoV-2) can cause more severe disease, potentially with cardiac and other multi-organ involvement resulting in prolonged return to training.[67] The classification system that has been published in this study may serve as an important and useful tool for physicians and researchers to distinguish between ARill and ARinf. We recommend that a clear diagnosis of ARill is reported in future studies.

What are the findings?

⇒ Acute respiratory illness (ARill) is the most common illness affecting athletes, and these are mostly acute respiratory infections (ARinf).
⇒ ARill can result in time loss from training and competition.

How might it impact on clinical practice in the future?

⇒ The overall incidence of ARinf in athletes is 4.9/1000 athlete days, which translates to approximately 1.8 ARinf per athlete per year.
⇒ Upper ARinf were the most common respiratory tract illnesses.
⇒ A higher incidence of ARinf was found in non-elite athletes than in elite athletes.
⇒ The incidence of ARinf is similar in older and younger athletes and across studies conducted in summer and winter.
⇒ The incidence of ARinf across different methods of diagnosis are similar.
⇒ In clinical practice the diagnosis of ARinf should be based on physician clinical assessment including laboratory confirmation of the pathogen where possible.
⇒ Self-reported symptoms using validated questionnaires or checklist could be used for screening of ARinf and in cases where physician diagnosis or laboratory testing is not feasible.

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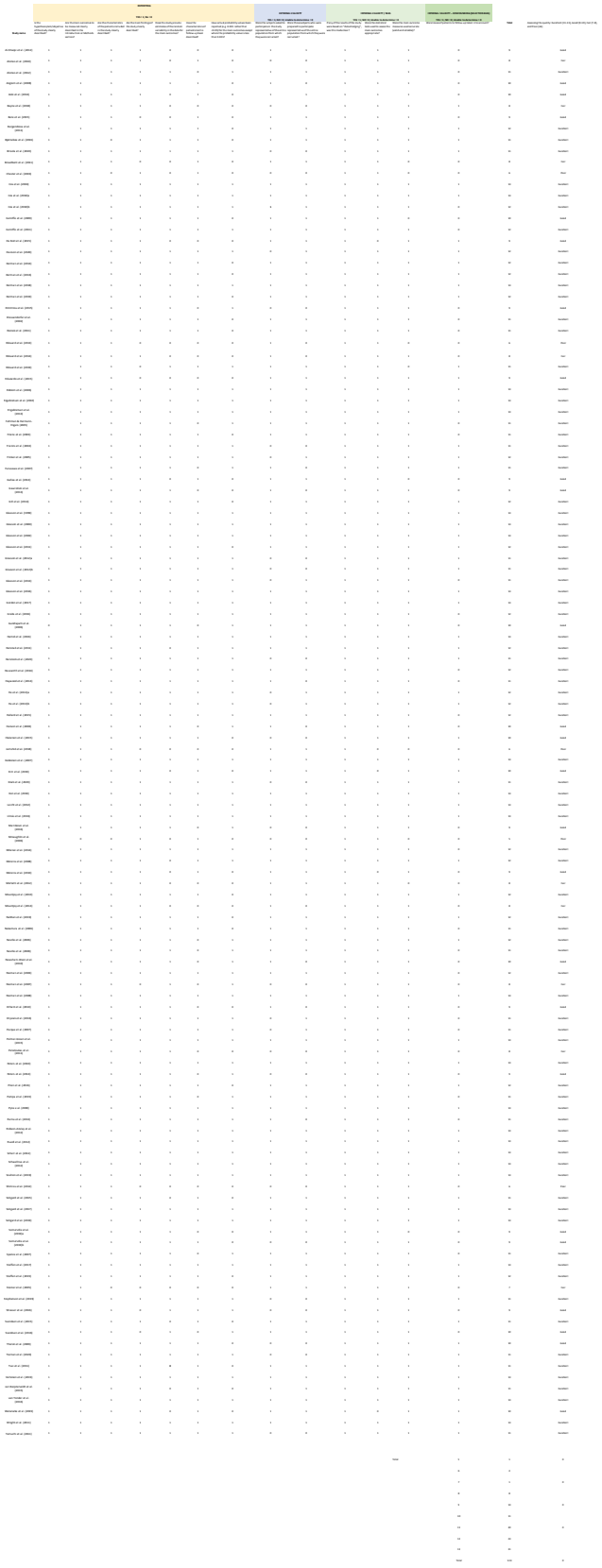
Author, Year	Study Design	Sport/Sporting Event	Olympic and Paralympic Studies	ARI diagnostic methodology	ARI category	ARI anatomical classification	Level of Athlete	Age Group	Sex		Season	Total Participants	Positive Illness Cases	Period Studied (days)	Quality Assessment Score (Total)	Level of Evidence (OCEBM)
Al-Shaqsi et al. (2012)	Prospective cohort	Mixed beach sports	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	736	396	Summer	1132	34	9	9	3b
Alonso et al. (2010)	Prospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	n/a	n/a	Summer	1979	41	9	8	3b
Alonso et al. (2012)	Prospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	n/a	n/a	Summer	1512	49	9	11	3b
Anglem et al. (2008)	Prospective cohort study	Adventure racing	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	18	9	Spring	27	5	14	10	3b
Aoki et al. (2014)	Retrospective cohort study	Judo	Other	Physician diagnosis including pathology confirmed (PCR or culture) for pathogen	Infective ARI confirmed	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	12	0	Spring	23	14	15	10	3b
Bayne et al. (2018)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	56	0	Summer	56	5	280	8	3b
Bere et al. (2015)	Prospective cohort	Handball	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	384	0	Winter	384	31	18	9	3b
Bergendiova et al. (2011)	Double-blind, placebo-controlled RCT	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	12	13	Not specified	25	21	84	12	1b
Bjørneboe et al. (2016)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	-	n/a	n/a	Summer	-	1072	-	11	3b
Brisola et al. (2020)	Prospective cohort	Waterpolo	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	0	20	Summer	20	8	105	11	1b
Broadbent et al. (2011)	Prospective cohort	Triathlon	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	n/a	n/a	All year	15	2	356	8	3b
Chester et al. (2003)	Retrospective cohort study	Athletics	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	-	127	74	Not specified	199	191	1068	6	2b
Cox et al. (2004)	Double-blind, placebo-controlled crossover trial	Running	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	20	0	Not specified	20	12	600	13	1b
Cox et al. (2010)a	Double-blind, placebo-controlled crossover RCT	Running	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	15-35 yrs	20	0	Not specified	20	9	112	13	1b
Cox et al. (2010)b	Double-blind, placebo-controlled RCT	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	16	4	Autumn	18	14	42	12	1b
Cunniffe et al. (2009)	Prospective cohort	Rugby	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	-	n/a	n/a	Not specified	30	123	336	10	1b
Cunniffe et al. (2011)	Prospective cohort	Rugby	Other	Self-reported symptoms with physician check (no examination)	Unspecified ARI	Upper ARI	Elite or Professional	-	31	0	All year	31	123	336	12	1b
Da Boit et al. (2015)	Randomised controlled trial	Mixed sports	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Recreational	15-35 yrs	11	6	Summer	17	8	112	9	1b
Davison et al. (2020)	Prospective randomised controlled trial	Mixed endurance (runners, triathletes, cyclists)	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	60	63	Summer	123	95	84	12	1b
Derman et al. (2014)	Prospective cohort	Summer paralympic/sports	Paralympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	-	n/a	n/a	Summer	3329	152	14	12	3b
Derman et al. (2016)	Prospective cohort	Winter paralympic/sports	Paralympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	15-35 yrs, >35 yrs	418	129	Winter	547	37	12	12	3b
Derman et al. (2018)	Prospective cohort	Summer olympics/sports	Paralympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	15-35 yrs, >35 yrs	2268	1389	Summer	3657	133	11	13	3b
Derman et al. (2019)	Prospective cohort	Winter paralympic/sports	Paralympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	15-35 yrs	433	134	Winter	567	28	12	12	3b
Dimitriou et al. (2015)	Double-blind, placebo-controlled RCT	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	6	4	Autumn	10	5	8	9	2b
Dressendorfer et al. (2002)	Prospective cohort	Cycling	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Recreational	15-35 yrs	9	0	Winter	9	5	98	11	3b
Dvorak et al. (2011)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	736	0	Not specified	736	40	30	11	3b
Edouard et al. (2013)	Prospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	6828	5766	Winter	440	8	3	6	3b
Edouard et al. (2014)	Prospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	n/a	n/a	Summer	136	12	5	8	3b
Edouard et al. (2019)	Retrospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	-	n/a	n/a	Summer, Winter	12594	164	59	11	2b
Eduoardo et al. (2015)	Prospective cohort	Athletics	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	n/a	n/a	Winter	577	8	4	9	2b
Ekblom et al. (2006)	Prospective cohort	Marathon running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	-	1354	340	Summer	1694	610	42	13	2b
Engebretsen et al. (2010)	Prospective cohort	Winter paralympic/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	1522	1045	Winter	2567	113	17	13	3b
Engebretsen et al. (2013)	Prospective cohort survailence study	Summer olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	5892	4676	Summer	10568	310	17	13	3b
Fahlman & Hermann-Engels (2005)	Prospective cohort	American Football	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive AND Recreational	15-35 yrs	75	0	All year	75	21	356	11	1b
Filaire et al. (2003)	Prospective cohort	Soccer	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	20	0	All year	20	2	356	11	1b
Francis et al. (2004)	Prospective cohort	Swimming	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	23	11	Spring, Summer	34	9	30	11	2b
Fricker et al. (2005)	Prospective cohort	Running	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	20	0	Winter	20	15	120	12	1b
Furusawa et al. (2007)	Prospective cohort	Wheelchair marathon	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	21	0	Autumn	21	8	42	11	3b
Gallea et al. (2014)	Prospective cohort	Iditarod Sled Dog race	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Recreational	-	n/a	n/a	Not specified	71	9	14	9	3b
Gawroński et al. (2013)	Prospective cohort	Summer paralympic/sports	Paralympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	>35 yrs	123	68	Summer	191	48	37	9	3b
Gill et al. (2014)	Prospective cohort	Ultra endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	19	6	Summer	25	7	30	12	1b
Gleeson et al. (1999)	Prospective cohort	Swimming	Other	Physician diagnosis including pathology confirmed (PCR or culture) for pathogen	Infective ARI confirmed	Upper ARI	Elite or Professional	15-35 yrs	16	9	Autumn, Spring	25	23	196	13	1b
Gleeson et al. (2000)	Prospective cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	12	10	Not specified	22	10	84	13	1b
Gleeson et al. (2002)	Prospective cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	14	0	Spring, Summer	14	9	30	13	1b
Gleeson et al. (2011)	Randomised controlled trial	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	n/a	n/a	Not specified	42	10	112	12	1b
Gleeson et al. (2012)a	Prospective cohort	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	28	38	Winter	80	74	120	11	1b
Gleeson et al. (2012)b	Double-blind, placebo-controlled RCT	Mixed endurance (running, cycling, swimming, triathlon, team, racket sports)	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	46	34	Not specified	66	29	112	11	1b
Gleeson et al. (2013)	Prospective cohort	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	44	31	Not specified	75	6	120	11	1b
Gleeson et al. (2016)	Randomised controlled trial	Mixed	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	156	112	Not specified	268	113	140	13	1b
Gordon et al. (2017)	Prospective cohort	Endurance running	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or competitive	-	31540	22366	Summer	53906	172	3	13	2b
Grabs et al. (2016)	Randomised controlled trial	Running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	162	0	Summer	162	142	35	12	1b
Gundlapalli et al. (2006)	Prospective cohort	Mixed sports	Olympic	Physician diagnosis including pathology confirmed (PCR or culture) for pathogen	Infective ARI confirmed	Upper ARI	Elite or Professional	15-35 yrs, >35 yrs	n/a	n/a	Winter	41	13	60	10	3b
Hamid et al. (2016)	Prospective cohort	Mixed summer sports	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	167	109	Autumn	276	33	26	13	3b
Hanstad et al. (2011)	Prospective cohort	Winter Olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	74	25	Winter	99	4	19	12	1b
Hanstock et al. (2020)	Randomised controlled trial	Mixed endurance (cyclists, triathletes)	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs, >35 yrs	25	0	Not specified	27	14	28	11	1b
Hauswirth et al. (2014)	Prospective cohort	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35yrs	n/a	n/a	Not specified	27	8	42	12	2b
Haywood et al. (2014)	Single blind placebo-controlled RCT	Rugby	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	30	0	Winter	30	35	84	11	1b
He et al. (2013)a	Prospective cohort	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	>35 yrs	70	169	Winter	239	102	120	12	1b
He et al. (2013)b	Prospective cohort	Mixed endurance	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	n/a	n/a	Winter	225	103	112	12	2b
Hellard et al. (2015)	Prospective longitudinal cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	15-35 yrs	14	14	Not specified	28	135	12859	12	1b
Henson et al. (2008)	Double-blind, placebo-controlled RCT	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	>35 yrs	18	3	Summer	21	5	14	10	1b
Ihalainen et al. (2015)	Prospective cohort	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Unspecified ARI	Upper ARI	Amateur or Trained or Competitive	>35 yrs	25	0	Winter	25	19	84	10	2b
Jamshid et al. (2018)	Prospective case-control	Wrestling	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Elite or Professional	15-35 yrs	40	0	All year	40	65	365	6	2b
Kekkonen et al. (2007)	Double-blind, placebo-controlled RCT	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	n/a	n/a	Summer	58	23	112	13	1b
Kim et al. (2019)	Retrospective cohort study	Winter olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	n/a	n/a	Winter	1639	107	25	10	3b
Knab et al. (2020)	Prospective cohort	Swimming	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	19	16	Not specified	35	16	175	11	1b
Kon et al. (2010)	Prospective cohort	Speed skaters	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	6	2	Not specified	8	2	5	13	3b
Leicht et al. (2012)	Prospective cohort	Wheelchair rugby	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs, >35 yrs	13	1	Spring, Summer	14	3	150	13	1b
Llinás et al. (2016)	Prospective cohort	Mixed (Cali World Games)	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	1608	1216	Summer	2824	7	10	13	3b
Marinkovic et al. (2016)	Double-blind, placebo-controlled RCT	Mixed sports (badminton, triathlon, cycling, alpinism, athletics, karate, savate, kayak, judo, tennis, swimming)	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	14	5	Not specified	19	11	98	9	2b
McLaughlin et al. (2006)	Prospective cohort	Adventure racing	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	213	107	Autumnn	320	13	10	5	3b
Milanez et al. (2014)	Prospective cohort	Futsal	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	0	8	Not specified	8	4	35	12	2b
Moreira et al. (2008)	Prospective cohort	Basketball	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	15	0	Not specified	40	10	38	12	3b
Moreira et al. (2010)	Prospective cohort	Basketball	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	14	0	Winter	4	1	17	9	3b
Mortatti et al. (2012)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	n/a	n/a	Not specified	15	7	28	8	3b
Mountjoy et al. (2010)	Prospective cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	-	134	108	Not specified	14	9	20	12	3b
Mountjoy et al. (2014)	Retrospective / Prospective cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs, >35 yrs	500	610	Summer	1116	778	112	8	3b
Nabhan et al. (2019)	Prospective cohort	Winter paralympic/sports	Olympic	Self-reported symptoms only	Unspecified ARI	Upper ARI	Elite or Professional	15-35 yrs, >35 yrs	12	0	Summer	1745	91	17	12	3b
Nakamura et al. (2006)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	35	0	Winter	242	34	25	11	3b
Neville et al. (2006)	Prospective cohort	Sailing	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	38	0	Summer	12	5	68	12	1b
Neville et al. (2008)	Prospective longitudinal cohort	Sailing	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs, >35 yrs	137	47	Not specified	35	48	518	11	1b
Newsham-West et al. (2010)	Retrospective cohort study	Adventure racing	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs, >35 yrs	22	9	All year	38	102	350	10	3b
Nieman et al. (2003)	Retrospective cohort study	Running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	>35 yrs	40	0	Summer	184	95	180	12	3b
Nieman et al. (2007)	Double-blind, placebo-controlled RCT	Cyclists	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	4	0	Summer	31	10	14	8	2b
Nieman et al. (2008)	Prospective cohort	Cycling	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	n/a	n/a	Not specified	17	6	14	13	1b
Orhant et al. (2010)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	81	0	All year	81	161	1068	9	1b
Orysiak et al. (2016)	Prospective cohort	Ice hockey	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	n/a	n/a	Winter	27	59	168	11	1b
Pacque et al. (2007)	Prospective cohort	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	13	4	Spring	17	7	28	11	3b
Palmer-Green et al. (2015)	Prospective cohort	Winter paralympic/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	15-35 yrs	33	23	Winter	56	25	25	13	3b
Patatoukas et al. (2011)	Retrospective cohort study	Disability sports	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Lower ARI	Elite or Professional	15-35 yrs, >35 yrs	115	24	Summer	139	1	11	8	3b
Peters et al. (2010)	Longitudinal observational field study	Endurance running	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Recreational	15-35 yrs, >35 yrs	14	0	Winter	14	19	42	13	1b
Peters et al. (2014)	Prospective cohort	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs, >35 yrs	30	0	Winter	30	9	22	9	3b
Prien et al. (2016)	Retrospective / prospective cohort	Swimming	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	15-35 yrs, >35 yrs	1151	1262	Summer	2413	312	42	12	3b
Pumpa et al. (2019)	Double-blind, placebo-controlled RCT	Rugby	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	n/a	n/a	Winter	19	4	189	11	1b
Pyne e al. (2000)	Prospective cohort	Swimming	Other	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	15-35 yrs	21	20	Winter	41	18	42	13	1b
Rama et al. (2013)	Prospective cohort	Swimming	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	13	6	Winter	19	31	203	11	3b
Robson-Ansley et al. (2012)	Prospective cohort	Endurance running	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Recreational	15-35 yrs, >35 yrs	n/a	n/a	Spring	138	65	16	13	3b
Ruedl et al. (2012)	Prospective cohort	Winter olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	15-35 yrs	560	461	Winter	1021	52	10	13	3b
Scherr et al. (2012)	Prospective, volunteer- and observer-blinded, placebo-controlled RCT	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Recreational	>35 yrs	121	0	Autumnn	121	42	56	13	1b
Schwellnus et al. (2012)	Prospective cohort	Rugby	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	259	0	Summer	259	144	112	13	1b
Scullion et al. (2019)	Prospective cohort	Rugby, Rowing	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Elite or Professional	15-35 yrs	40	13	Summer, Winter	53	46	180	13	3b
Shimizu et al. (2012)	Prospective cohort	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	0	21	Not specified	21	21	30	6	3b
Soligard et al. (2015)	Prospective cohort	Winter olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	-	1704	1210	Winter	2780	159	17	11	3b
Soligard et al. (2017)	Prospective cohort	Summer olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	-	1659	1121	Summer	11274	292	17	13	3b
Soligard et al. (2019)	Prospective cohort	Winter paralympic/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	6185	5089	Winter	2194	194	17	13	3b
Somerville et al. (2019)a	Prospective longitudinal cohort	Rugby	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	-	81	0	Winter	81	43	240	9	1b
Somerville et al. (2019)b	Double-blind, placebo-controlled RCT	High school sports (type not determined)	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	4	8	Autumn, Winter	12	7	63	9	2b
Spence et al. (2007)	Prospective cohort	Triathlon	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	15-35 yrs	35	28	Summer	63	11	140	11	1b
Steffen et al. (2017)	Prospective cohort	Winter olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	581	502	Winter	1083	66	10	13	3b
Steffen et al. (2019)	Prospective cohort survailence study	Summer olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Unspecified ARI	General (unclassified) ARI	Elite or Professional	15-35 yrs	2003	1983	Summer	3986	168	13	12	3b
Steiner et al. (2005)	Prospective cohort	Mixed sports	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	Upper ARI	Elite or Professional AND Recreational	-	n/a	n/a	Summer	204	43	712	7	1b
Stephenson et al. (2019)	Prospective longitudinal cohort	Summer paraplympic/sports	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional	>35 yrs	6	1	Summer, Winter	7	22	238	11	2b
Strasser et al. (2016)	Double-blind, placebo-controlled RCT	Unstated	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	5	10	Winter	33	16	84	9	2b
Svendsen et al. (2015)	Prospective cohort	Cross-country skiing	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Elite or Professional	15-35 yrs	27	17	Winter	42	17	38525	11	2b
Svendsen et al. (2016)	Retrospective cohort	Nordic ski	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	22	17	Not specified	39	410	2920	10	2b
Theron et al. (2009)	Prospective cohort	Soccer	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	n/a	n/a	Winter	184	20	15	10	3b
Tiernan et al. (2020)	Prospective cohort	Rugby	Other	Self-reported symptoms only	Unspecified ARI	Upper ARI	Elite or Professional	15-35 yrs	19	0	Not specified	19	12	70	11	1b
Tsai et al. (2011)	Prospective cohort	Tae kwon do	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	16	0	Not specified	16	10	49	11	1b
Valtonen et al. (2019)	Prospective cohort	Winter olympics/sports	Olympic	Physician diagnosis including pathology confirmed (PCR or culture) for pathogen	Infective ARI confirmed	Upper ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs	31	13	Winter	44	20	17	13	2b
van Beijsterveldt et al. (2015)	Prospective cohort	Summer olympics/sports	Olympic	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	n/a	n/a	Summer	2272	12	6	11	3b
van Tonder et al. (2016)	Prospective cohort	Endurance running	Other	Self-reported symptoms with checklist and algorithm to diagnose	Infective ARI suspected	General (unclassified) ARI	Elite or Professional AND Amateur or Trained or Competitive	15-35 yrs, >35 yrs	3952	3079	Summer	7031	896	12	13	3b
Watanabe et al. (2019)	Prospective cohort	Mixed winter sports	Other	Physician (diagnosis by history and clinical examination)	Infective ARI suspected	General (unclassified) ARI	Elite or Professional	-	0	0	Winter	1164	17	6	10	3b
Wright et al. (2011)	Retrospective / prospective cohort	Swimming	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Amateur or Trained or Competitive	15-35 yrs	14	13	Spring	27	26	49	13	2b
Yamuchi et al. (2011)	Prospective cohort	Rugby	Other	Self-reported symptoms with physician check (no examination)	Infective ARI suspected	Upper ARI	Elite or Professional	15-35 yrs	32	0	Not specified	32	6	30	11	1b



Online Supplementary 4: Forest plots

Figure 1: Incidence rate (IR) of all studies that investigated ARill (n=124). The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

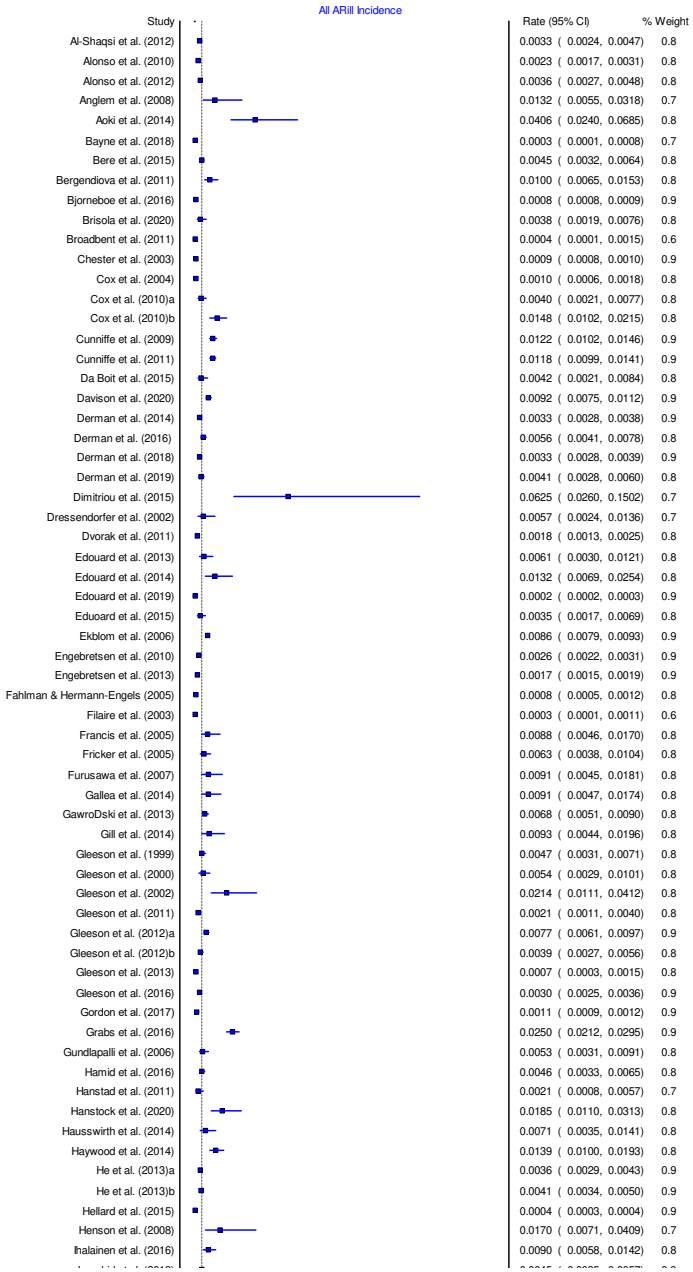


Figure 1 (continued): Incidence rate (IR) of all studies that investigated ARill (n=124). The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

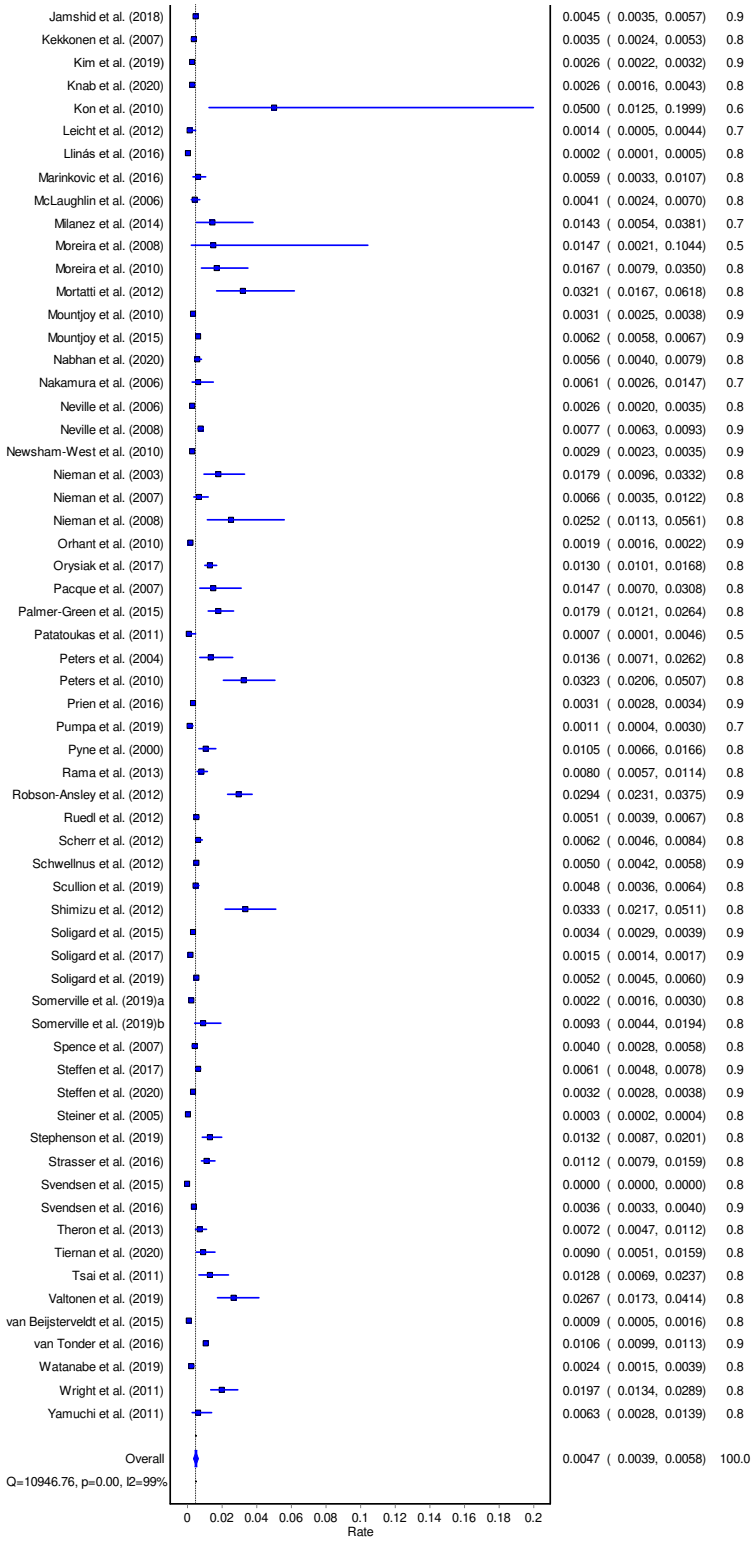


Figure 2: Incidence rate (IR) of studies that investigated undiagnosed ARill (n=17). The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

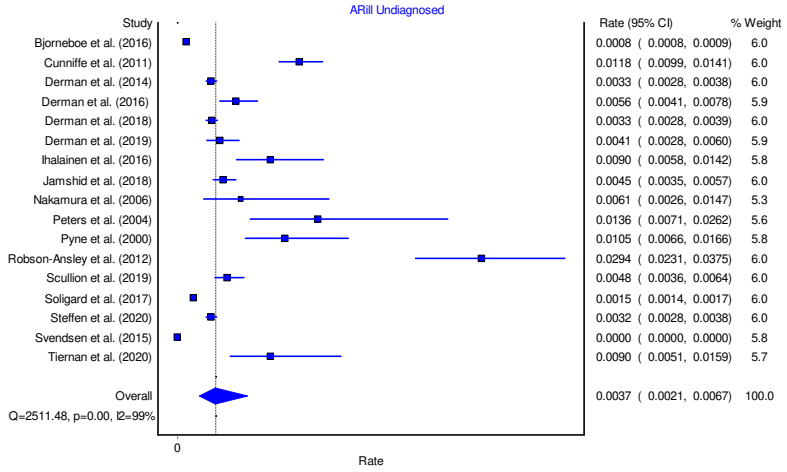


Figure 3: Incidence rate (IR) of studies that investigated ARinf (n=107) by pathological classification. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

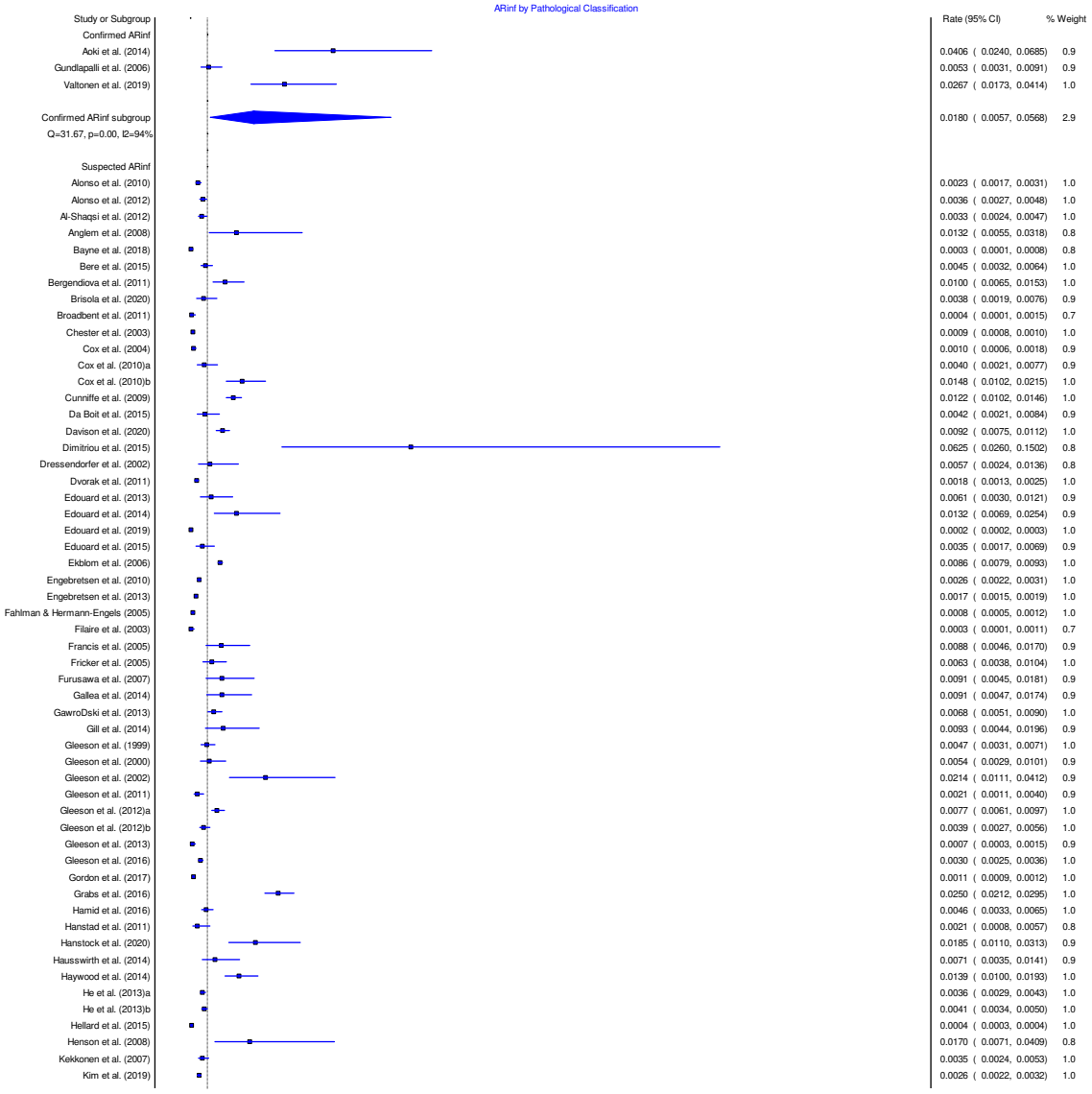


Figure 3 (continued): Incidence rate (IR) of studies that investigated ARinf (n=107) by pathological classification. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

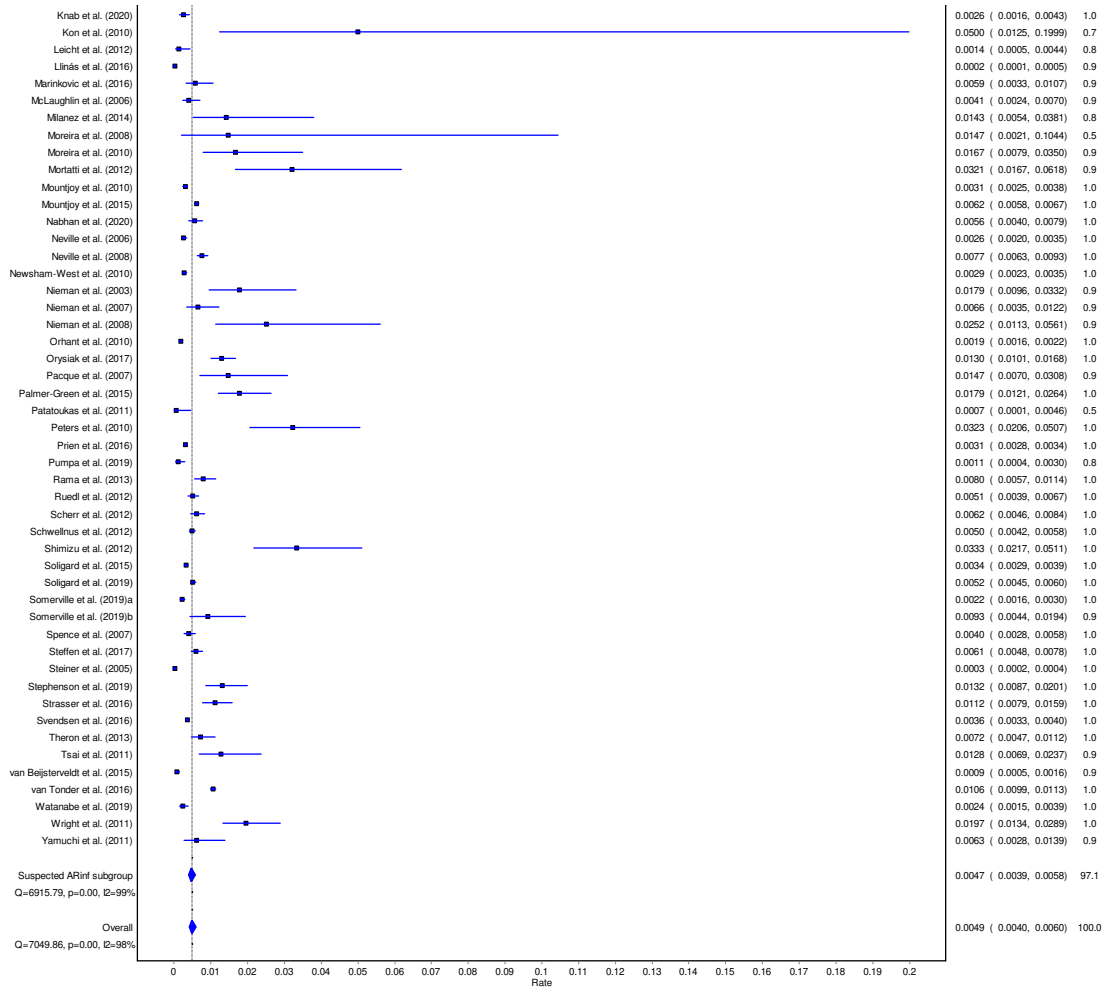


Figure 4: Incidence rate (IR) of studies by methods to diagnose ARinf (n=107). The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

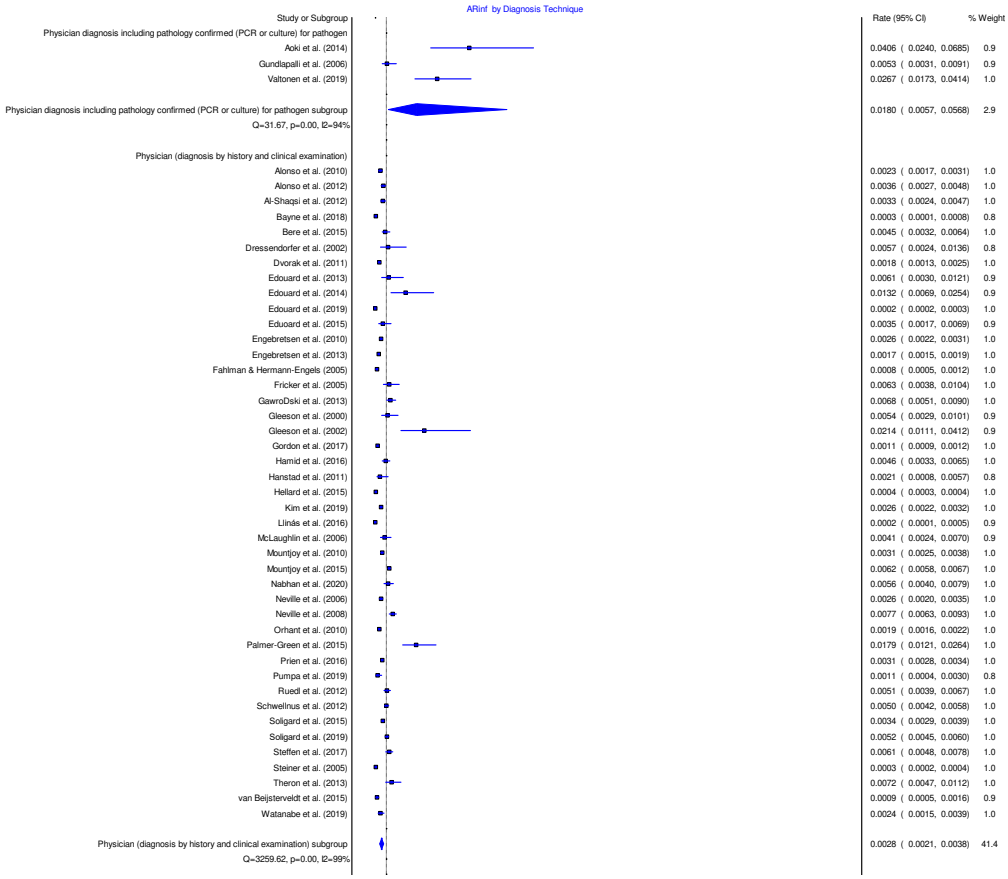


Figure 4 (continued): Incidence rate (IR) of studies by methods to diagnose ARinf (n=107). The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

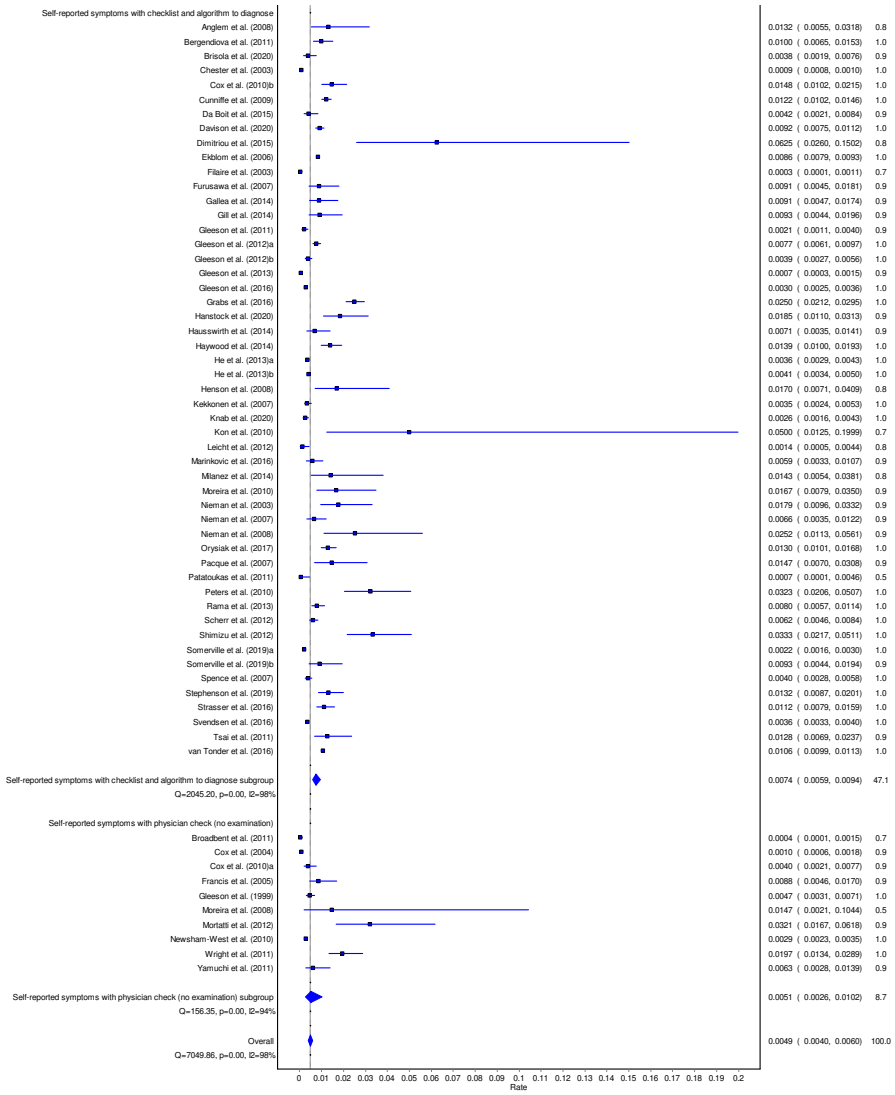


Figure 5: Incidence rate (IR) of studies that investigated ARinf (n=72) by athlete's level of performance. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

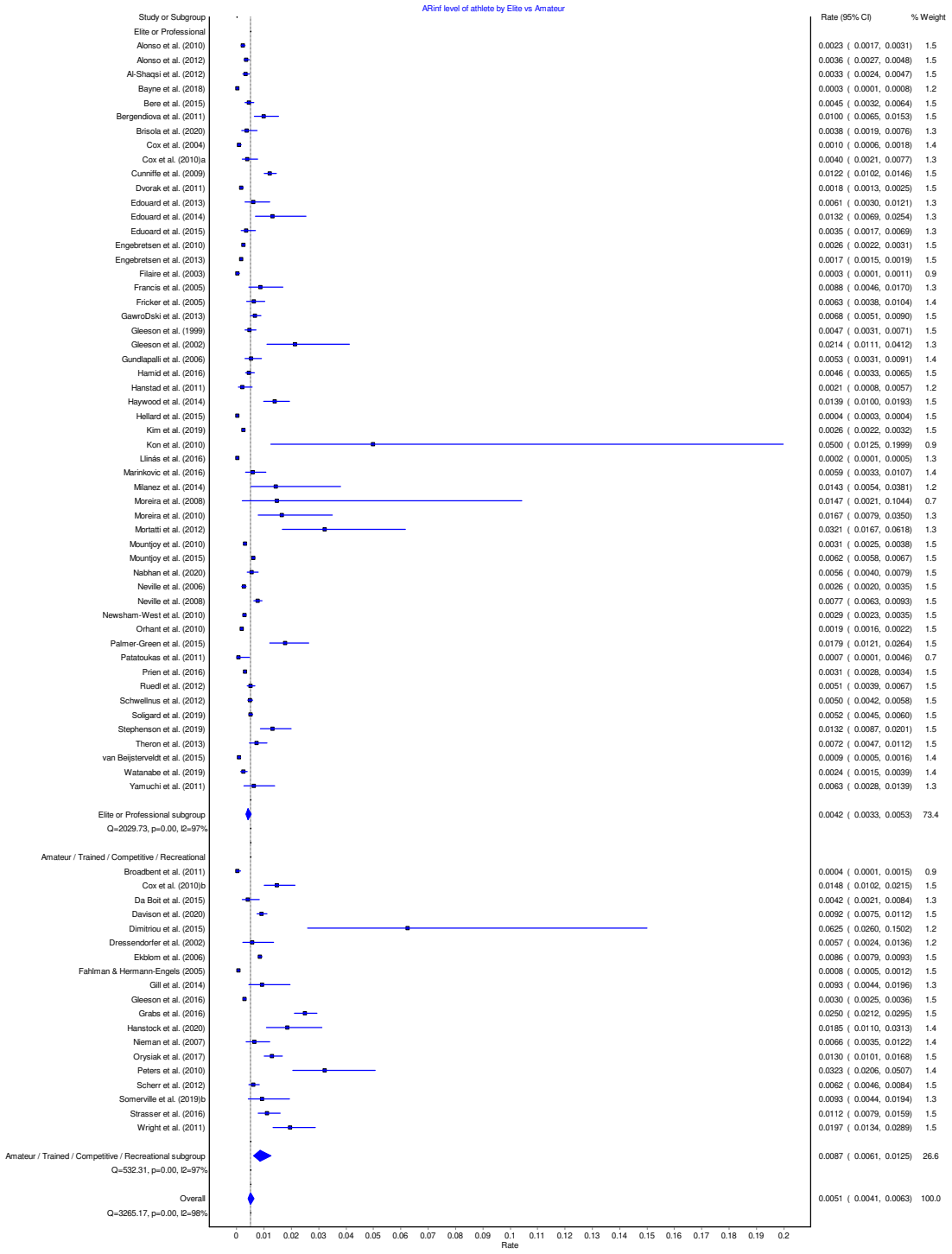


Figure 6: Incidence rate (IR) of studies that investigated ARinf (n=56) by age group. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

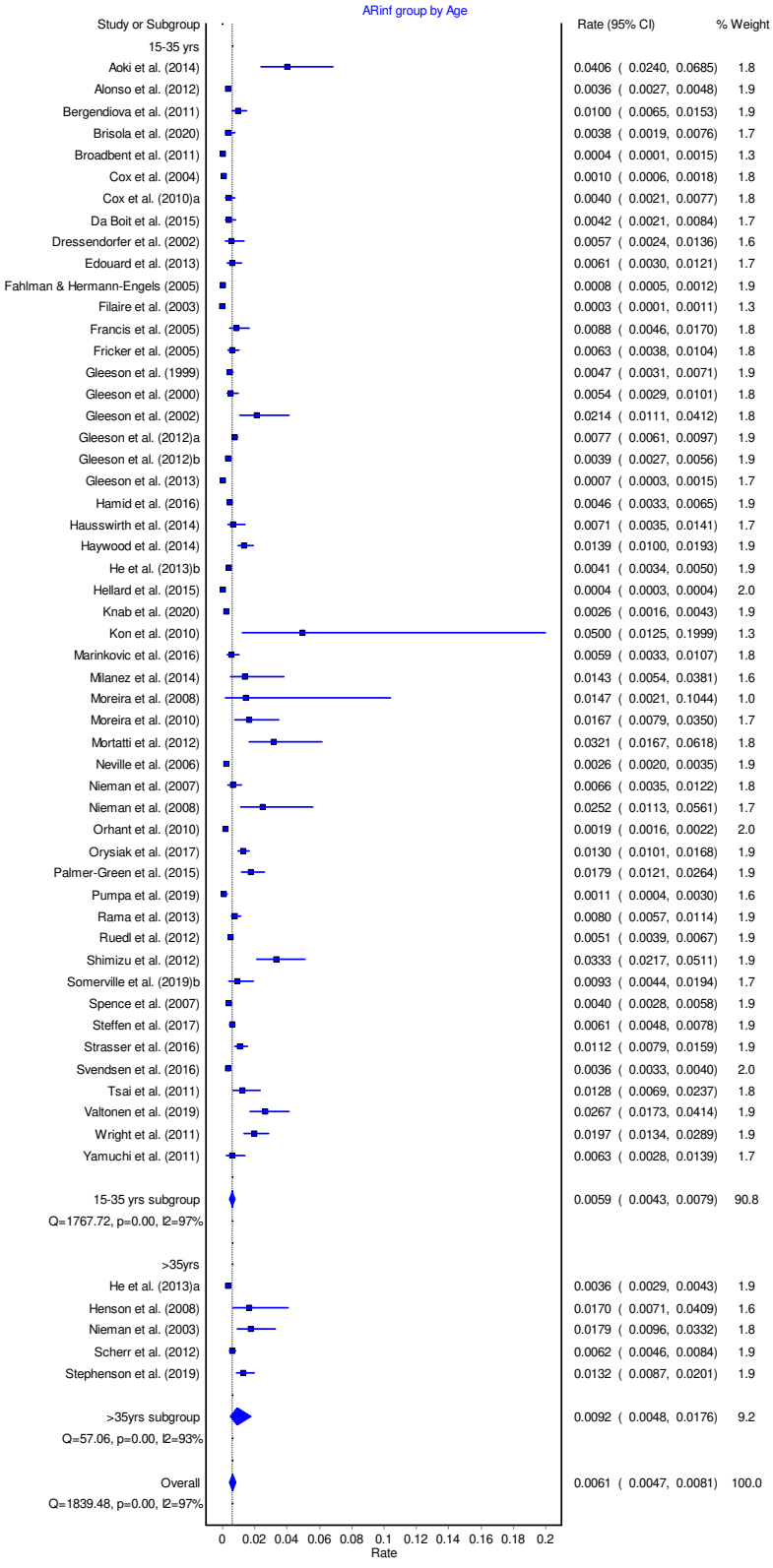


Figure 7: Incidence rate (IR) of studies that investigated ARinf (n=57) by season. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

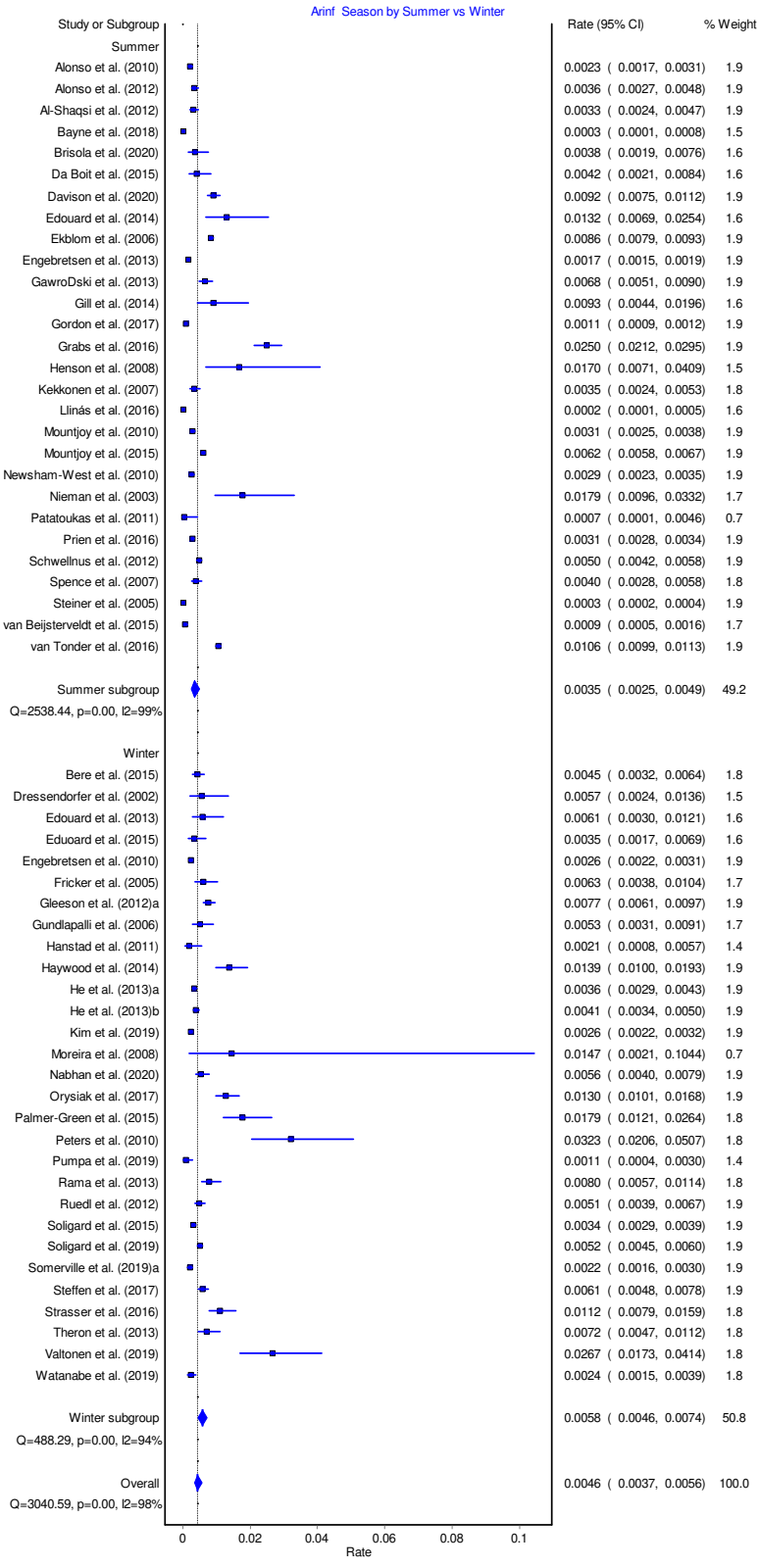


Figure 8: Incidence rate (IR) of studies that investigated ARinf (n=107) by quality of the article. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.

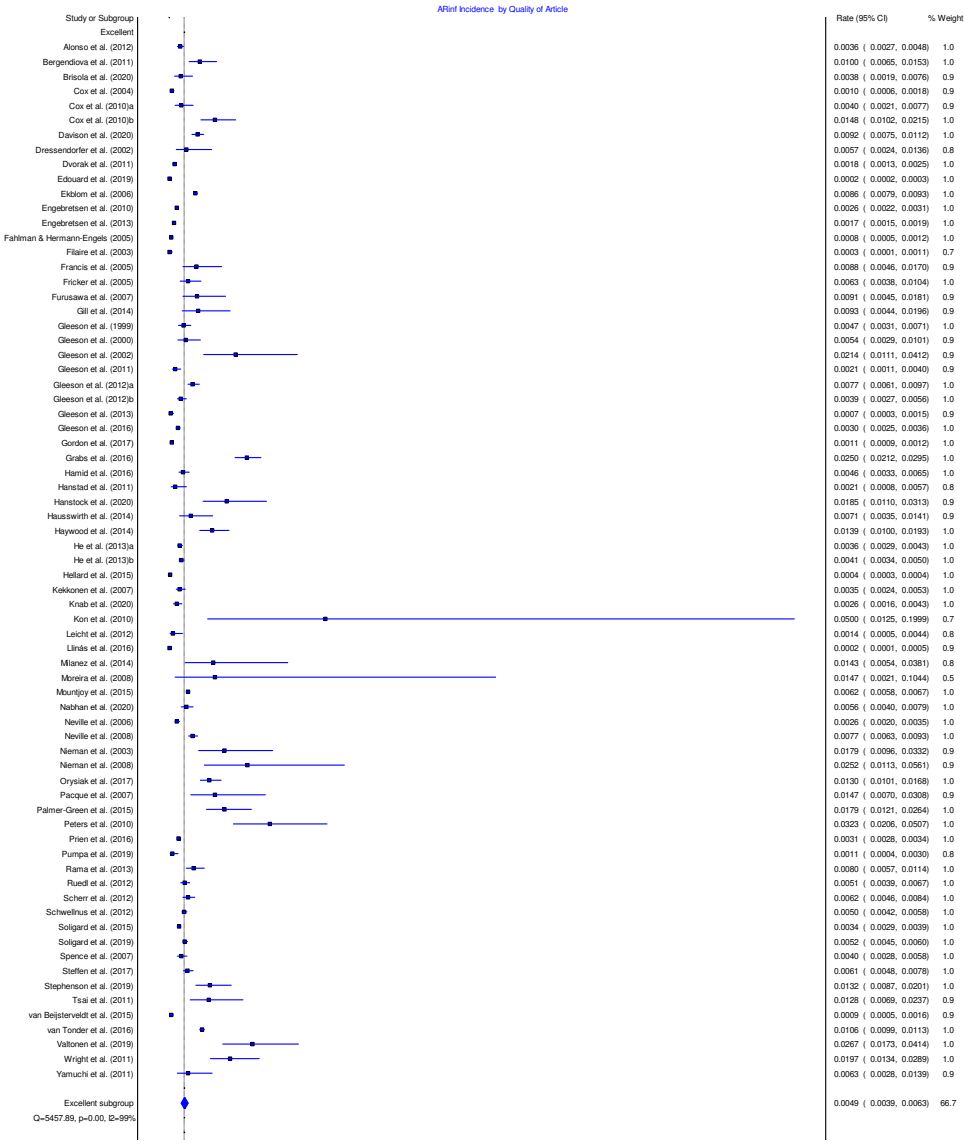


Figure 8 (continued): Incidence rate (IR) of studies that investigated ARinf (n=107) by quality of the article. The individual studies that were included are presented on the left of the forest plot. The IR (95% confidence interval (CI)) per athlete day (multiply by 1000 for IR per 1000 athlete days) is presented on the right including the weight that the corresponding study exerts in the meta-analysis.