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Obstructive Sport Apnea (OSA) and contact sports: A systematic review and meta-analysis

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ABSTRACT

Obstructive sleep apnea (OSA), a frequently under-diagnosed sleep disorder, may lead to future poor health, performance, and wellbeing. Increased OSA prevalence has been reported in individuals who have had a head injury.

We systematically searched EMBASE, PSYCINFO, WEB OF SCIENCE, COCHRANE and PUBMED to 18th June 2022. OSA prevalence and demographic data was extracted according to PRISMA guidelines from 14 eligible studies with 6,116 participants, with study quality assessed using the modified Downs and Black Score.

Meta-analysis of proportions yielded a pooled OSA prevalence of 30.0% (95% confidence interval (CI), 24.0–36.0%) with significant heterogeneity between studies (I^2 = 94.4%, $p<0.001$). Sub-group analysis by different sports gave OSA prevalence of: American football (29% (95%CI: 22–36%); Rugby (35.0% (95%CI: 24.0–47.0%)) and 'other contact' sports (31% (95%CI: 24.0–37.0%)). Prevalence was higher in retired (from play) (34.0% (95%CI: 25.0–44.0%)) v current (21.0% (95%CI: 10.0–32.0%)) American football players.

The prevalence of OSA in contact sports was higher than that reported in the general population, especially in retired American Football players. Further high-quality longitudinal studies in a wider range of contact sports are required to explore OSA prevalence and its possible effects on participants performance and current and future health.

Introduction

Obstructive sleep apnea (OSA), is a sleep disorder that is characterised as a reduction in air supply during sleep with partial (hypopneas) and full collapses (apneas) of the upper airway (larynx) [20]. OSA severity is determined by the apnea-hypopnea index (AHI) based upon the number apneas and hypopneas that occur in an hour during sleep, with an AHI of 5 and over being classed as mild OSA [44]. It is reported an estimated 2 to 4% of adults in the UK are diagnosed with OSA [34], but evidence suggests that 85% of people with OSA in the UK are undiagnosed and therefore untreated [25,28]. Whilst OSA traditionally was considered to be caused by and, primarily impacting, obese, sedentary, middle-aged men, there is increasing evidence to challenge this perspective [22]. Younger and more active populations are now diagnosed with OSA, including athletes ([30,36]). This includes individuals with normal body mass index (BMI) of 18 to 25 and non-asthmatics [11,17]. Furthermore, many athletes are of healthy weight and have superior cardiovascular and respiratory health [13,21] and it is possible that OSA in these individuals could be due to other factors. Individuals with non-disabling head injuries may be at increased risk of OSA [4] which may be of relevance to individuals who partake in contact sports as they are at risk from concussion injuries.

The aim of this study was to conduct, what is to our knowledge, the first systematic review of the prevalence OSA in contact sports, defined as Rugby Union and League, Soccer, Australian Rules Football, American Football, Boxing, Wrestling, Mixed Martial Arts, Judo, Karate, Field Hockey, Ice Hockey, and Lacrosse. Consideration to the different methodologies that have been deployed for the assessment of OSA was given.

Method

Initial scoping searchers were undertaken for different types of contact sport and sleep / sleep apnea. For our purposes, full-contact sports are defined as those sports with regulations that facilitate full body en-

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gagements between participants. Semi-contact sports are defined as having contact regulated to limited physical interactions with participants. Sports that did not have any published articles were not included in the subsequent systematic review: as such, the scoping research narrowed the search field for the systematic review to search to five full contact sports (American Football, Australian Rules Football, Ice Hockey, Rugby League & Rugby Union), four semi-contact sports (Boxing, Karate, Judo & Wrestling) and three limited contact sports (Field Hockey, Lacrosse & Soccer). The presentation of results has been completed in line with Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines (PRISMA; [24]). The result synthesis has been through the narratives of outcomes presented in the studies [40] and the prevalence of OSA was taken from the studies or calculated from the percentage reported in the studies.

Search strategy

Systematic searches were to identify studies that reported a prevalence of OSA in contact sports. Electronic searches were performed from 1974 to 18th June 2022 of EMBASE, PSYCINFO, WEB OF SCIENCE, COCHRANE and PUBMED. The search terms for the included sports, with varying levels of contact, and obstructive sleep apnea are listed in the appendix.

Exposure

Study participants were required to have or previously played a contact sport, to any level or for any length of time.

Outcome

The studies had to have directly tested the participants that are athletes or previous athletes in a contact sport for OSA or have utilised a validated diagnostic screening method to screen the cohort of participants for OSA.

Inclusion criteria

Included studies had to fulfill the following criteria: The papers had to include one of the desired sports, to have details of OSA diagnosis and prevalence. The papers could be retrospective or prospective and incorporate surveys, polysomnography or actigraphy at any level of performance or participation.

Exclusion criteria

Papers were excluded when duplicate studies from the same cohort, if it was a conference or meeting abstract or unpublished material.

Data extraction

The searches returned 662 records. Of these records 187 were duplicates. The records underwent an initial title and abstract review. This yielded 28 records for full text analysis which was completed double blind by two authors (NH and AW) and any disagreements were resolved through negotiation with a third reviewer (MM), only one paper required the third author. Reasons for exclusion: four because the rates of OSA were undeterminable, three papers from the same cohort with the fourth included, one was a scoping review, one protocol paper and six missing an OSA diagnosis, prevalence, and quantification. Thereby, 14 papers have been included for this systematic review (see Fig. 1) from which data was extracted for the metan analysis.

Fig. 1. PRISMA flow diagram for this systematic review.

Methodological quality assessment

The quality of the 14 included studies was evaluated by the modified Downs and Black [7] Quality Index score system which has a maximum score of 22 for studies of this type, with higher scores representing higher quality. (See appendix Table A1). This scoring process was blind and independent to the full text analysis, with two research independently scoring (NH and AJP).

Meta-analysis

The binominal results from the studies, the number of OSA cases against the total in the cohort are the numerator and denominator which has been utilised to produce confidence intervals. The meta-analysis was conducted using Stata v17 ([33]), a p-value <0.05 is considered statistically significant. Metan is a statistical program implemented to perform meta-analyses of proportions in Stata. Metan implements procedures which are specific to binomial data and allows computation default score test-based confidence intervals and pooled proportions [35]. We calculated the pooled prevalence with 95% confidence intervals (CI) for the combined contact sports group. Heterogeneity between studies was tested by Q-statistic and quantified by the H-statistic and I^2 statistic [12]. Funnel plot asymmetry was used to assess publication bias. Sensitivity analysis was used to determine the influence of individual studies in the meta-analysis by omitting one study at a time, from most to least deviated, and observing the effect on the pooled estimates. Potential sources of heterogeneity were further explored in sub-group analysis we calculated the pooled prevalence (95%CI) in each of the different sports, in current and retired American football players and in American football players by age (mean population age: <25 or ≥25 years of age).

Results

Of the records, 14 had studies that met the inclusion criteria. The studies came from the following sports: American Football (*n* = 9) Rugby Union (*n* = 2), Rugby League (*n* = 1), Judo (*n* = 1), and Ice Hockey (*n* = 1). No records were yielded from Lacrosse, Field Hockey, Soccer, Australian Rules Football, Mixed Martial Arts, Karate, Wrestling, Boxing. Of the nine studies of American Football players five studies included only retired players [1,13,21,37,43] and four current players ([6,10,16,29]).

For current players, two studies included National Football League players (NFL) [10,29] two studied college football players ([6,16])

Table 1 presents the studies included in this review, their sports, method, participants, and the result of the number of participants with OSA and percentage of the study cohort.

OSA assessment method

One American Football study used polysomnography, alongside self-reported screening [10]. Four American Football studies used sleep studies ([1,16,21,29). Two studies of American Football Players used pervious diagnosis [13,43]. One study for American Football used photoplethysmography. In Rugby two studies used polysomnography [3,8]. The other Rugby study used sleep studies [14]. The Ice Hockey study used a combination of self-reported screening and sleep counselling leading polysomnography (Tumilehto *et al.*, 2017). For Wada et al. [41] in Judo they used sleep studies.

BMI and OSA in contact sport athletes

Three studies directly compared BMI and OSA rates ([6,14,29]). None of these studies report any relation between BMI and OSA rates (Table 1). The remaining studies have not included BMI data or analysis (Table 1).

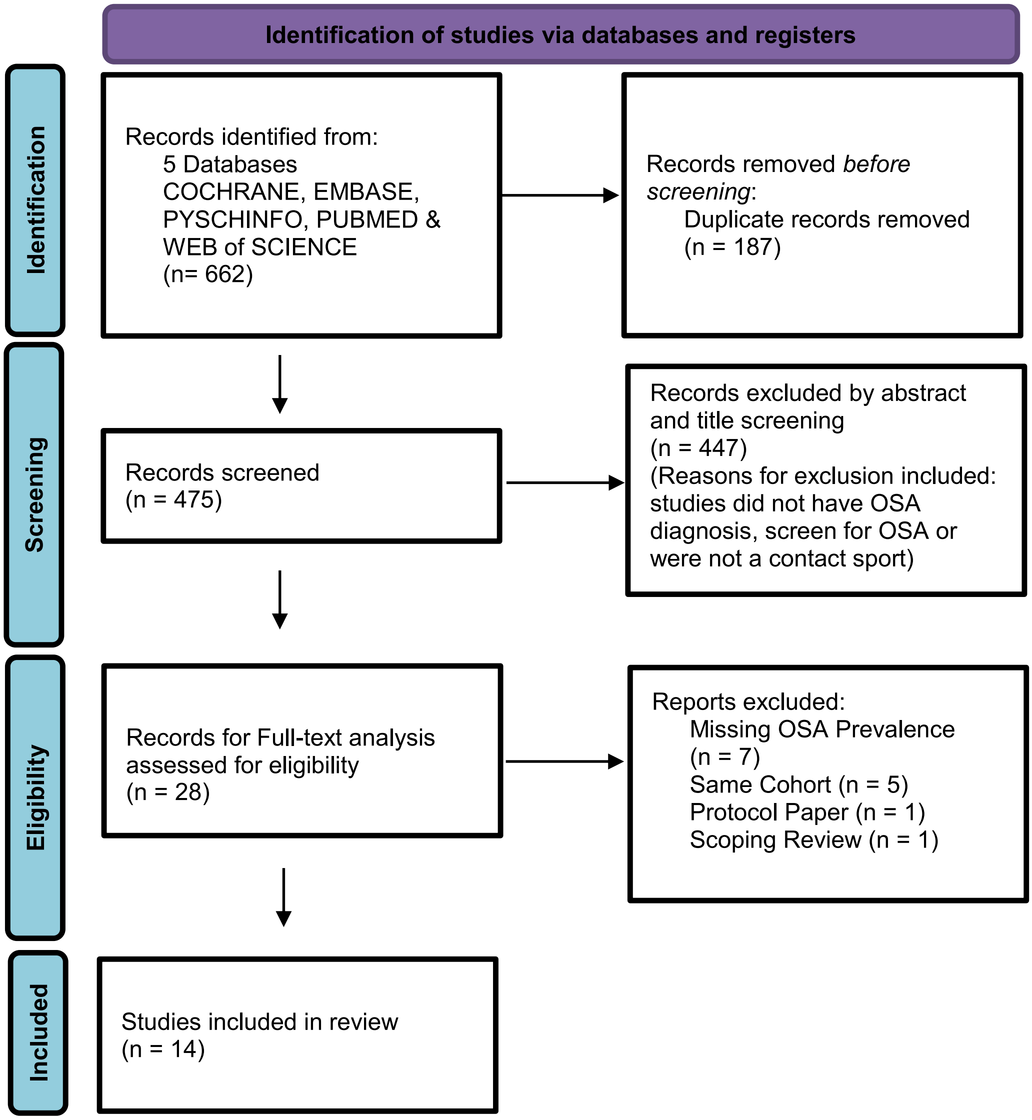

Fig. 1. PRISMA flow diagram for this systematic review.

Quality assessment

The modified Downs and Black [7] score across the 14 included papers gave a mean score of 12.71 (±2.27) out of 22 with a range of 10 to 17 (see Table 1). Some studies lack sufficient power, and it was unclear if some were representative of the entire population. randomization has not been undertaken in any of the included studies (Table A1). Most studies cannot be adjudged on question 11, 12, and 24. Studies should identify the source of their population and be representative of the entire population. The proportion agreeing to participate should be validated to be represent the confounding factors of the source population. All studies were non-randomised for screening.

Meta-analysis

The meta-analysis demonstrated that the overall prevalence of OSA in contact sports was 30% (95% CI, 24 to 36%). There was significant heterogeneity between the studies (I^2 = 94.4%, p<0.001) Fig. 2 and evidence of publication bias (data not shown).

Sub-group analysis

a By contact sport

American football: The Prevalence of OSA in American football was 29.0% (95%CI: 22.0–36.0%) with significant heterogeneity (I^2 = 95.9%, p<0.001). Rugby: The prevalence was 35.0% (95%CI: 24.0–47.0%) with no evidence of heterogeneity (I^2 = 29.7%, p = 0.24). Other contact sports: This included one Judo and one Ice Hockey study with a combined prevalence of OSA of 40.0% (95%CI: −0.14%–94.0%) and significant heterogeneity (I^2 = 95.9%, p<0.001).

a By player status (Retired (from play) v current) in American football players.

The prevalence in retired American Football players was 34.0% (95%CI: 25.0–44.0%) with significant heterogeneity (I^2 = 96.8%, p<0.001). The prevalence in current American Football players was current (21.0% (95%CI: 10.0–32.0%)) with significant heterogeneity (I^2 = 90.8%, p<0.001) see Fig. 2(b).

a American Football Players by age (mean population age greater and equal to or less than 25 years of age)

The prevalence in American Football players <25 years of age was 34.0% (95%CI: 5.0–62.0%) with significant heterogeneity (I^2 = 96.4%, p<0.001). The prevalence in those ≥25 years of age was 27.0% (95%CI: 20.0–35.0%) with significant heterogeneity (I^2 96.4%, p<0.001) see Fig. 2(c).

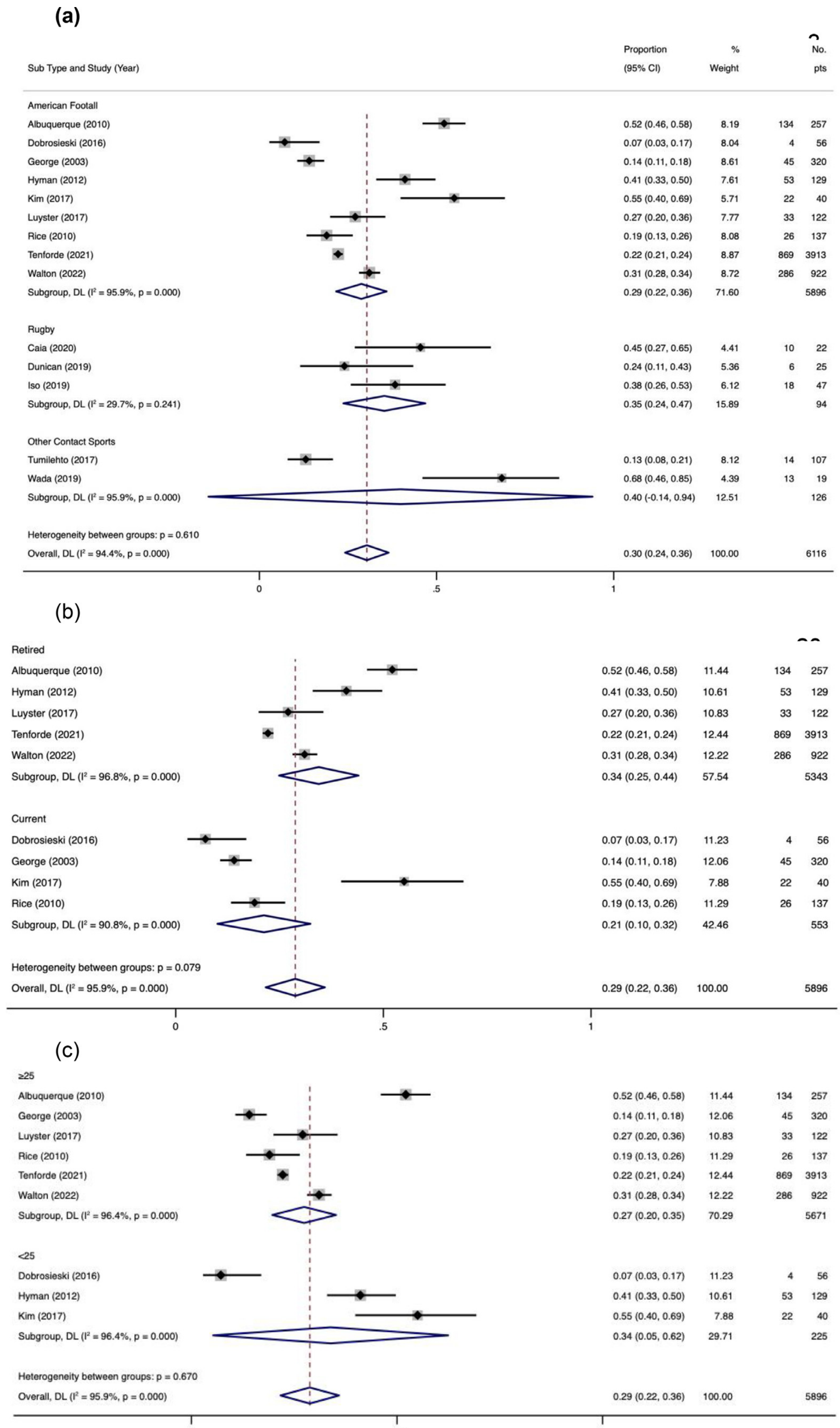

Fig. 2. Forest Plot 2 Forest plots of the meta-analysis (a) For all the included studies, sub-categorised into American Football, Rugby, and 'Other' contact sport studies. (b) American Football studies by player status as either retired or current athletes. (c) American Football by average age of either <25 or ≥ 25 years. The right-hand columns are number of cases of OSA and, total of participants in the cohort.

Table 1
Description of included studies.

Paper	Sport	OSA assessment method	Number and status of Participants, Age (Mean & SD yrs)	Number of participants with OSA (Prevalence%)	Details of BMI and other sub-group analysis within studies	Modified Downs and Black Quality Score.Max (best quality) score=22
American Football: Retired						
Albuquerque et al. [1]	American Football	Overnight Sleep Study (non-PSG)	257 Retired Players (53.9 ± 1.0)	134 (52.3%)	No sub analysis	10
Hyman et al. [13]	American Football	Previous Diagnosis	129 Retired Players (42.2 ± 7.7)	53 (41.1%)	Position sub analysis	13
Luyster et al. [21]	American Football	Overnight Sleep Study (non-PSG) with matched comparison	122 Retired Players (45.3 ± 4.2)	33 (27.0%)	Positional sub analysis	16
Tenforde et al. [37]	American Football	Self-Reporting Questionnaire	3913 Retired Players (**)	869 (22.0%)	No sub analysis	17
Walton et al. [43]	American Football	Self-Reporting Questionnaire	992 Retired Players (64.8 ± 8.9)	286 (31.0%)	No sub analysis	14
American Football: Current						
Dobrosielski et al. [6]	American Football	Overnight Photo-plethysmography	56 Current College Players (19.8 ± 1.4)	4 (8.3%)	OSA group (33.0 ± 5.4) vs non-OSA group (27.6.0 ± 3.6)	13
George et al. [10]	American Football	Screening Questionnaire and Polysomnography	320 Screened Current NFL Teams and 52 for PSG (25.5 ± 2.7)	(~14.0%) *	Position sub analysis not OSA diagnosis	14
Kim et al. [16]	American Football	Overnight Sleep Study (non-PSG)	40 Current College Players (18.1 ± 0.5)	22 (55.0%)	No BMI data reported	12
Rice et al. [29]	American Football	Overnight Sleep Study (non-PSG)	137 Current NFL Players (27.0 ± 1.0)	26 (19.0%)	No significant difference between BMI and OSA.	15
Rugby						
Caia et al. [3]	Rugby League	Home-based Polysomnography	22 Current Players (23.8 ± 3.6)	10 (45.5%)	Positional analysis	10
Dunican et al. (2019)	Rugby Union	In-clinic Polysomnography	25 Current Players (25.0 ± 4.0)	6 (24.0%)	Positional analysis	11
Iso et al. [14]	Rugby Union	Overnight Sleep Study (non-PSG)	47 Current Players (18.6 ± 0.5)	18 (38.3%)	OSA (27.5 ± 5.0) vs non-OSA (27.8 ± 3.2)	10
Other Contact Sports						
Tuomilehto et al. [38]	Ice Hockey	Survey Screening and Home-based Polysomnography	107 Current Players (24.4 ± 0.9) 23 for PSG	14 (13.0%)	No sub analysis	11
Wada et al. [41]	Judo	Overnight Sleep Study (non-PSG)	19 Current Players (**)	13 (63.0%)	No BMI data report	12

*George et al. [10] screened all the 320 participants with only 52 for an overnight polysomnography with an overall estimate of 14% of the 320 participants.
**Unable to determine the mean age or standard deprivation.

Sensitivity analysis

i) All American football players: For the sensitivity analysis, we deleted one study at a time, but this had no effect on the overall heterogeneity.
ii) Retired American football players: The stepwise removal of one study at a time had no major effects on the heterogeneity.
iii) Current players: The stepwise removal of one study at a time had no major effects on the heterogeneity.
iv) By Downs and Black Score: Removing the poore quality studies (with a Downs and Black Score <12) had no major effect on the heterogeneity (I^2 = 93.3%; p<0.001) within the retired athletes or current athletes (I^2 = 67.5%; p = 0.046). Further removal of a study with a score of 13.([[6]]) reduced the heterogeneity such that it was no longer significant in the current players (I^2 = 37.9%, p = 0.204) but additional removal of the studies with a score of 13 had no effect on the heterogeneity in the retired players which remained significant.

Discussion

This is the first review to our knowledge that has specifically focused on contact sports and the prevalence of OSA in athletes. There was a large degree of heterogeneity and indication of publication bias. Notwithstanding the limitations it does show that the level of OSA in contact sports (30.0% (95% CI, 24.0–36.0%)) is much higher than that reported in the general population (2.0–4.0%; [34]) and further analysis was conducted to explore the possible reasons for this we conducted and sub-group by sport, player status (current v retired) and age as well as sensitivity analysis

In American Football the overall, prevalence of OSA in retired and current American football players was 29.0% (95% CI: 22–36%) n = 5896 (Fig. 2(a)). The majority of these were retired (n = 5343) and whilst the sub-group analysis indicated that the prevalence of OSA might be higher in retired as compared to current players there was no evidence of heterogeneity between groups but the heterogeneity within groups was still highly significant (Fig. 2(b)). Retired players are likely to be older Walton *et al.* [43] and since the likelihood of OSA diagnosis in the general population increases with age [9] we conducted a separate analysis by age. The calculated mean prevalence was higher in the older players with a mean age of twenty-five years or above than in the participants who were less than 25 years of age but here was no evidence of heterogeneity between groups. There was however significant heterogeneity within the groups. It is however of concern that for example, in one study conducted in American Football players from a college year group of 18 (±0.5) years of age, the reported prevalence of OSA was as high as 55.0% (95% CI: 40.0–69.0%) by Kim *et al.* [16] see Fig. 2c.

The reported prevalence in Rugby players was similar to that reported for the American football players and appeared more consistent with detected heterogeneity within the group. There were only two 'other' sports. One study in Ice hockey players and one in Judo players. The prevalence in these players appearing to be particularly high but the study only included 19 current players (see Fig. 1(a)).

Mechanisms

OSA has the potential to be caused through multiple pathophysiologies which athletes are exposed to in contact sports. Obesity has the potential to increase adipocytes (fat cells) around the neck [31]. It is commonly thought a restriction in airflow resulting in apneas and hypopneas of the larynx is caused by excess tissue [5]. Contact sport athletes might not just have fat cells, but also might have more neck muscle which compresses the larynx.

This review demonstrates that contact sports have a higher OSA risk rate than the general population, 30% (95% CI, 24.0–36.0%) compared to 2 to 4%. But whilst these athletes may have a high BMI, they may not have a higher fat level or sedentary lifestyle, which is expected to have a positive impact on OSA and be protective in preventing OSA [19], suggesting that other factors may be important such as head injuries. Additionally, Luyster *et al.* [21] and Hyman, Daug and Liu (2012) have suggested that BMI and size of players is less impactive for OSA risk with greater muscle mass and fitness levels of the players studied. From Table 1 it can be see that only three of the possible fourteen studies have considered BMI in their analysis ([6,14,29]). Albequerque *et al.* [1] concluded that lineman in American Football were more likely to have OSA and be obese and George *et al.* [10], demonstrated that of their fourteen OSA sufferers, twelve were lineman and that lineman had a higher BMI, yet no association between BMI and OSA or adjustment for BMI was reported in their analysis. Positions maybe important in considering head injury or impact exposure.

Likewise, Hyman *et al.* [13] demonstrated that BMI and lineman increased the risk of OSA. Additionally, Kim *et al.* [16] showed that the American Football players with OSA were more likely to be heavier and be lineman, however, did not include BMI as a measure. Rice *et al.* [29] concluded there is an increase in BMI increased for lineman but did not have a greater prevalence and severity nor a significant relationship with rates of OSA. On the other hand, Luyster *et al.* [21] demonstrated that higher risk of OSA in their retired cohort non-linemen and there was no increased risk with obesity. Dobrosielski *et al.* [6] reported that high risk factors with BMI and neck size, but there was no difference in prevalence with two were high risk of OSA and two were low risk of OSA with two being lineman. In Rugby League and Union, despite a difference in positions, with forwards more likely to have OSA, without an association with BMI increasing OSA prevalence ([3,38]). Iso *et al.* [14] has not compared positions, yet there was no association between BMI and OSA prevalence. Therefore, there is contradictory evidence around the size being the cause of OSA in contact sport, reinforcing those other mechanisms are potentially involved.

It is possible that other mechanisms might be important in contact sports players. The maintenance of the larynx lumen (space for the air to flow) is regulated by nervous impulses from the medulla oblongata [18]. OSA has been associated with concussive head injuries, with OSA prevalence seemingly higher than the 3–5% of the general population with 78% of this post-concussion syndrome cohort with OSA [32]. Concussion is a frequent injury in the NFL [26] and a recent systematic review [39] found that Rugby (both Union and League) had a concussion prevalence of 28.85 per 10,000 athlete exposures, compared to 8.72 in American Football, 7.87 in Ice Hockey, 4.03 Lacrosse and 3.71 for Soccer. Subconcussive head impacts are also commonplace in contact sports, which could alter the biochemistry, microstructures and functioning in the brain [23]. Interestingly, Walton *et al.* [43] has demonstrated that OSA was significantly associated with greater mild cognitive impairment. The association between concussion and sub concussive head injuries in sport alongside OSA requires further investigation.

Limitations

All the studies in this review are cross-sectional, giving the current rate of OSA in the cohort at a specific time. Across the studies in this review different methods have been utilised to assess the athletes and rate of OSA in the cohorts. This has resulted in limitations in the quality of the data. For sleep research the *gold standard for the* assessment of OSA is in laboratory polysomnography [10], which was undertaken in two studies ([8,10]). However, overnight home-based polysomnography also gives high quality sleep data and was used amongst two studies [3,38]. The most common method utilised by six studies [1,6,14,16,41]) in this review was an overnight sleep study which involved monitoring of airflow or oxygenation (in the case of [6]). The latter sleep studies may be less accurate than full polysomnography and may lead to under detection of cases [10]. Self-reported questionnaires were used in two studies to collect information for previously diagnosed OSA ([43] Brett *et al.*, 2021; [37]), despite being an effective method for mass delivery and data collection, the method requires the participant to have been diagnosed previously, which is problematic given that most people are not diagnosed. Luyster et al. [21] is the only study to use healthy matched control but only provided information for sleep apnea risk from the Berlin Sleep Questionnaire.

The type of sleep study used to determine the prevalence of OSA is important as each different method will use different crirteria to define the OSA diagnosis. For example with Polysomnography is used by elven number of studies OSA was determined by an objective measure of sleep apnea AHI ([1,3,6,8,14,16,21,41,43]) where as the studies using questionnires [37,43] relied on previous diagnosis of OSA. This means that there is no objective measure or AHI attached to the individuals. Additionally, it relies on the opportunity for diagnosis in the course of the athletes life. Hyman, Dang & Liu [13], has similar methodological challenges, they used previously diagnosed OSA during clinic visits whilst assessing participants for obesity. Therefore, relying on the recognition of symptoms previously, especially thwart method with the underdiagnosis of OSA [15,28].

The polysomnography and overnight sleep studies employed different methods in screening their cohorts for OSA. George *et al.* [10] undertook screening of participants with high and low risk participants and have not screened all participants, this increases the risk that OSA cases have been missed. Despite comparisons between groups of high and low risk, there is an assumption that the screening is sensitive to each case of OSA. As evidenced in George *et al.* [10] OSA can be present in those with a lower risk of OSA. Additionally, further weaknesses exist within the study with a randomization of the participants with high and low risk, so the estimation of 14% might not be accurate and the study has the Apnea-Hypopnea Index (AHI) for OSA as >10 AHI (events hour^{-1}), whereas the other studies have the more recently accepted AHI>5 events hour^{-1} for OSA diagnosis. In Tuomilehto *et al.* [38] only those suspected of OSA, 23 of 107 participants, were included in a home-based polysomnography study. Caia *et al.* [3] and Dunican *et al.* ([9]) included all their cohort for a polysomnography study. However, Dunican *et* al. ([9]) undertook laboratory-based polysomnography are not reflective of their sleep environment, so home-based studies may yield better quality sleep ([27]). Overnight sleep studies whether actigraphy or photoplethysmography (uses light spectrometry like actigraphy but more in-depth and especially for peripheral circadian rhythms; [2]), occurred in the home setting. Although they can be disruptive in the home environment, they should reflect the experience of sleep.

Data quality

Overall, the quality of the papers was lower than what would be desired for comprehensive research papers. This is a consequence of the methods employed to survey the prevalence of OSA in a population and a lack of clarity in the population representation. The lowest score on the modified Down and Black was ten out of the possible 22, with three papers being assessed at this level [3,14]. Albuquerque et al. [1] and Iso et al. [14] had a lower score in part as they were not full research papers. Albuquerque et al. [1] research correspondence and Iso et al. [14] was a research letter.

Recommendations

Contact sports, and to a lesser extent all sports, should screen athletes for sleep disorders with both validated tools and with sleep studies. Previous evidence has suggested that over 25 years old have poorer sleep quality scores [42], so might benefit from sleep surveys. However, this review demonstrates that all ages of athletes should be screened and tested for a sleep disorder. Optimally this would be done throughout the season and an athlete's career, alongside sleep monitoring to allow for adequate rest and recovery for optimal performance [42].

Future research projects for current and retired athletes, should screen all participants for sleep disorders, instead of utilizing surveys asking if they have been diagnosed. Studies would benefit from incorporating overnight sleep studies even for those with a perceived lower risk of a sleep disorder such as those who are athletic More detailed data is required with regards to the players characteristics such as age and BMI to facilitate fully adjusted analyses. Longitudinal studies which follow up different cohorts, would enable researchers to understand how the rate changes in OSA with age and exposure to contact sports. It is also important that such studies have enough participants to ensure that they are adequately powered. The inclusion of matched controls would enable more detailed meta-analysis about the relative risk of OSA in those who do and don't participate in contact sports.

Conclusions

This study suggests that the prevalence of OSA in contact sports is around 30.0% (95% CI, 24.0–36.0%) but this may be higher as not all studies used overnight sleep studies to screen for sleep disorders. Whilst retired athletes have a higher prevalence than current athletes this may be age-related and furthermore detailed studies are required to conduct fully adjusted analyses. Player position might be important as there is a known difference in players report physique between playing positions, this requires further investigations. Some research suggests head impacts and exposure to repeated head impacts may be an alternative mechanism for developing OSA. The absence of data for popular full-contact (Australian Rules Football), semi-contact (Boxing and Fight Sports) and limited contact sports (Soccer) is palpable. Sleep disorders such as OSA are treatable, but if left to manifest can have detrimental impacts on performance, recovery, and general health of athletes. The impact of OSA can be lifelong and life limiting so regardless of causation it is an important consideration for athlete's health.

Appendix

A1. Search Terms:

Sports-

American Football, NFL, Gridiron, Rugby Union, Rugby League, Association Football, Football, Soccer, Ice Hockey, NHL, Hockey, Field Hockey, Lacrosse, Boxing, MMA, Mixed Martial Arts, Judo, Taekwondo, Wrestling, Jujitsu, Basketball, NBA, Gaelic Football, GAA

OSA- OSA, Sleep apnea, Sleep Apnoea, Obstructive Sleep Apnea, Obstructive Sleep Apnoea, Apnea-Hypopnea Index, Apnoea-Hypopnea Index, AHI

Table A1
Modified Downs and Black Score for included studies.

Modified Downs and Black Score																				
Authors	Year	1	2	3	5	6	7	10	11	12	16	17	18	20	21	22	24	27	Total	Sport
Albuquerque et al.	2010	1	0	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	10	American F
Caia et al	2020	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	1	10	Rugby L
Dobrosielski	2016	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	1	13	American F
Dunican et al	2019	1	1	1	0	1	1	0	0	0	0	1	1	1	1	1	0	1	11	Rugby U
George et al.	2003	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	14	American F
Hyman et al.	2012	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	1	13	American F
Iso et al	2019	0	1	1	0	1	1	1	0	0	0	1	1	1	0	1	0	1	10	Rugby U
Kim et al	2017	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1	0	1	12	American F
Luyster et al	2017	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	3	16	American F
Rice et al	2010	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	2	15	American F
Tendorde et al	2021	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	4	17	American F
Tuomilehto et al.	2017	1	0	0	1	1	1	1	0	0	0	1	1	1	1	1	0	1	11	Ice Hockey
Wada et al	2019	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1	0	1	12	Judo
Walton et al	2022	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	3	14	American F

Table 1 is the quality assessment of the papers in this review, utilizing a modified Downs and Black [7] score, the total of the quality assessment out of 22.
The included studies are represented with their first author, year, and the type of contact sport. The column represents the different sections of Downs and Black [7] which is being used to assess the quality of the studies. The different categories of quality scoring were out of one, apart from the power of the study (27) which is out five.
Items numbers 4, 8,9, 13–15, 19, 23, 25 and 26 from the Downs and Black Score are not relevant to this kind of analysis and have not been included or listed here.
The column item number relate to the assessed domains summarised briefly as follows:.
(1) Is the hypothesis/aim/objective of the study clearly described,.
(2) Are the main outcomes to be measured clearly described in the Introduction or Methods section?.
(3) Are the characteristics of the patients included in the study clearly described?.
(5) Are the distributions of principal confounders in each group of subjects to be compared clearly described?.
(6) Are the main findings of the study clearly described?.
(7) Does the study provide estimates of the random variability in the data for the main outcomes?.
(10) Have actual probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?.
(11) Were the subjects asked to participate in the study representative of the entire population from which they were recruited?.
(12) Were those subjects who were prepared to participate representative of the entire population from which they were recruited?.
(16) If any of the results of the study were based on “data dredging”, was this made clear?.
(17) In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?.
(18) Were the statistical tests used to assess the main outcomes appropriate?.
(20) Were the main outcome measures used accurate (valid and reliable)?.
(21)W ere the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?.
(22) Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?.
(24) Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?.
(27) Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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