Abstract

Objectives: Full-contact football-code team sports offer a unique environment for illness risk. During training and match-play, players are exposed to high-intensity collisions which may result in skin-on-skin abrasions and transfer of bodily fluids. Understanding the incidence of all illnesses and infections and what impact they cause to time-loss from training and competition is important to improve athlete care within these sports. This review aimed to systematically report, quantify and compare the type, incidence, prevalence and count of illnesses across full-contact football-code team sports.

Design/Method: A systematic search of Cochrane Library, MEDLINE, SPORTDiscus, PsycINFO and CINAHL electronic databases was performed from inception to October 2019; keywords relating to illness, athletes and epidemiology were used. Studies were excluded if they did not quantify illness or infection, involve elite athletes, investigate full-contact football-code sports or were review articles.

Results: Twenty-eight studies met the eligibility criteria. Five different football-codes were reported: American football (*n=10*), Australian rules football (*n=3*), rugby league (*n=2*), rugby sevens (*n=3*) and rugby union (*n=9*). One multi-sport study included both American football and rugby union. Full-contact football-code athletes are most commonly affected by respiratory system illnesses. There is a distinct lack of consensus of illness monitoring methodology.

Conclusions: Full-contact football-code team sport athletes are most commonly affected by respiratory system illnesses. Due to various monitoring methodologies, illness incidence could only be compared between studies that used matching incidence exposure measures. High-quality illness surveillance data collection is an essential component to undertake effective and targeted illness prevention in athletes.

Key words: epidemiology; athletes; respiratory tract infections; incidence; prevalence

Introduction

Athlete illness monitoring has become commonplace as the focus on protecting the health of the athlete has sharpened. Athlete illnesses most often result in time-loss or performance restriction from training and competition [1, 2]. A common cold or upper respiratory infection, which may seem trivial to the general population, can limit an athlete's potential to train and compete in major competitions [1, 3]. Athletes may also be at risk of contracting life-threatening viruses, such as hepatitis B, which are known to be transferred between contact sport players with exposed bleeding wounds [4]. Consequently, absence from training due to illness may limit success in elite sport [1, 2]. Additionally, athlete welfare could be impacted; a balanced approach to decisions made around athletes training and competing whilst suffering from an illness must be found to manage athlete welfare [5], therefore it is vital to understand the impact of illness in elite athletes.

Full-contact football-code team sports, such as American football, rugby union, rugby league, rugby sevens, Gaelic football and Australian rules football, offer a unique environment for illness risk. During training and match-play, players are exposed to high-intensity collisions which may significantly increase energy requirements [6] and potentially suppress immune function. The physical contact involved in these sports may also result in skin-on-skin abrasions and possible transfer of bodily fluids [7], such as blood or saliva. Contact sport athletes have been found to become colonised with bacterial infections faster and more frequently than non-contact sports [8] potentially due to increased physical contact, sharing of facilities, frequent international travel and busy competition schedules [9]. For example, players regularly share gym equipment, changing rooms and accommodation, as well as towels and water bottles [7, 10], despite guidelines highlighting the risk of illness associated with these activities [9]. Previous research has found that 25% of surfaces in high-school and college training room facilities tested positive for influenza [11] and that the sharing of personal items, such as soap, towels and water bottles was a significant risk factor for the spread of Methicillin-Resistant Staphylococcus Aureus (MRSA) infection [12].

Previous non-systematic reviews of infectious diseases in contact sports have highlighted that infections are commonly contracted during match-play and in the changing room environment [7, 13]. However, current reviews do not assess illnesses of specific origin, such as gastrointestinal or respiratory, despite upper respiratory illness accounting for up to 65% of illnesses presented at sports medical clinics [14]. Furthermore, these reviews do not quantify and compare type, incidence, prevalence or count of illness across full-contact football-code sports. As such, it is important to understand the incidence of all illnesses and infections and what impact they cause to time-loss from training and competition, to improve athlete care within these sports. Therefore, the aim of this systematic review was to report, quantify and compare the type, incidence, prevalence and count of illnesses across full-contact football-code team sports.

Methods

This systematic review was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analyses) guidelines [15] and was prospectively registered with the PROSPERO database (CRD42019120981). PubMed and The Cochrane Library, as well as MEDLINE, SPORTDiscus, PsycINFO and CINAHL (via EBSCOhost), were systematically searched from inception to 14th October 2019. Keyword searches were performed for: 'illness', 'ill', 'sick', 'sickness', 'infection', 'URTI', 'respiratory tract infection', 'respiratory tract infections', 'immune', 'immune function', 'immune-suppression', 'immunosuppression', 'immune tolerance', 'immunology', 'immunity', 'epidemiology', 'prevalence', 'incidence', 'monitoring', 'surveillance', 'athletes', 'athlete', 'sports', 'sport', 'player', 'players' (details of the search strategy are outlined in supplementary material one). Reference lists of eligible studies and review articles were also searched. No language or date of publication restrictions were applied during the searches.

After eliminating duplicates, search results were screened independently against the eligibility criteria by two researchers (LC and KF). Disagreements were resolved through discussion, or via a third researcher (KD) if required. References that were potentially eligible after screening the title and abstract were retrieved and evaluated for inclusion via full-text by two researchers (LC and SW). The titles and authors were not masked to the reviewers.

For inclusion, studies were required to meet the following criteria: human observational, prospective, retrospective, cross-sectional, longitudinal or intervention studies, participants in the studies were required to be elite level athletes of a full-contact football-code sport. Elite level was defined as academy or university competitors, semi-professional or professional competitors, national or international competitors, Olympic or world-class level competitors [16]. No restriction was placed on age or sex. Studies were excluded if they did not quantify illness or infection, involve elite athletes, investigate full-contact football-code sports (i.e. rugby union, rugby league, rugby sevens, Australian rules football, American Football, Gaelic Football) or were review articles. Studies where solely carriage of infection was outlined were also excluded.

Data relating to the participant and study characteristics (i.e. sex, age, stature, body mass, level of competition, sport, season phase, duration of study, total sessions assessed), illness and infection data (i.e. definition of illness, assessment method, type of illness/infection monitored, incidence of illness, prevalence of illness, illness/infection count, time-lost, quantity of symptoms presented) were extracted. For ease of comparison, metrics were converted to the same units as most other studies, i.e. stature is reported in centimetres (cm) and body mass in kilograms (kg). Where interventions were present in some studies, only data from control groups were extracted.

Articles were assessed in full using a modified version of the Downs and Black checklist for methodological quality [17] independently by two authors (LC and SW). Disagreements were resolved initially via discussion between the two independent reviewers; however a third reviewer was consulted for dispute resolution (BJ). A previous review in this research field [18] used this assessment scale, using only 19 (numbers 1–3, 5–7, 9–12, 16–18, 20–22, 25–27) of the 27 criteria that logically applied. As only data from control groups were extracted, questions relating to intervention were omitted. A score of ≥75% was deemed to indicate low risk of bias, 60%–75% moderate risk of bias and ≤60% high risk of bias [17, 18].

A meta-analysis was not performed as study designs were heterogeneous thus not able to be pooled.

Results

Through the original database search 5495 articles were identified. Following the removal of duplicates and screening for eligibility, 293 studies were reviewed for full-text. Twenty-eight articles were included in the systematic review for final analysis [19-46]. Figure 1 provides a schematic representation of the decision process. Despite meeting all eligibility criteria, two papers were excluded due to duplicated data. The authors were contacted to confirm that the data were the same before excluding the papers.

Five different football-codes were covered: American football (*n=10*) [19-23, 25, 30, 31, 34, 46], rugby union (*n=9*) [24, 32, 33, 38-40, 42, 43], rugby sevens (*n=3*) [28, 35, 41], rugby league (*n=2*) [27, 44] and Australian rules football (*n=3*) [26, 36, 45]. One multi-sport study included both American football and rugby union [29]. Twelve studies reported the sex of the participants directly [20, 23, 25-29, 32, 33, 35, 41, 42]. Fifteen studies reported the league/competition that the participants competed in, therefore the sex of participants could be inferred [19, 21, 22, 24, 30, 31, 34, 36-40, 44-46], and one study did not report the sex of participants or competition [43]. Of those studies that identified sex, eleven reported the sex split characteristics; 69% of studies were in male participants and 31% in females [20, 23, 25-29, 32, 33, 35, 42]. The representative level of participants in the studies included Olympic (n=3, 11%) [28, 35, 41], professional and national (n=15, 53%) [24, 26, 27, 32-34, 36-40, 42-45] and university/collegiate (n=10, 36%) [19-23, 25, 29-31, 46]. Most studies assessed adult elite athletes, only one reported assessment of youth elite athletes [35].

<FIGURE 1 NEAR HERE>

Study data from the included papers is outlined in supplementary material 2-5. The majority of studies *(n=12)* assessed all illnesses and infections [26, 28, 29, 33, 35-41, 45]. Five studies assessed MRSA skin infections [19, 20, 23, 34, 43] and three studies assessed heat illness [21, 22, 46]. The remaining studies assessed the presence of upper respiratory illness (URIs) *(n=4)* [25, 27, 42, 44] and upper respiratory tract infections (URTIs), gastro-intestinal and other infections *(n=2)* [24, 32]. Two studies did not define an explicit illness [30, 31]. A variety of illness definitions were used, with the majority using a medical attention/clinical diagnosis definition (*n=14*, 50%) [19-23, 26, 34, 35, 37-41, 46] and others using self-report (*n=7*, 25%) [24, 25, 27, 29, 32, 42, 44] and time-loss (*n=2*, 7%) [28, 33]. Two studies (7%) used a definition that included both time-loss and medical diagnosis [36, 45]. Three studies did not provide an explicit definition of illness (11%) [30, 31, 43]. Calculation of illness varied across studies, with a minority reporting illness as an incidence rate [21, 22, 26, 29, 38-40, 42, 46] or prevalence [28, 41]. Most studies gave numerical counts of illness episodes and some reported counts of symptoms. Three studies reported frequency of time-loss illnesses [38-40] and two others reported the number of days lost to illness [33, 34]. Studies ranged from 3 days [28] to three years [22, 31] in duration, and a multitude of scenarios, including both competition and training were assessed.

In studies which assessed all illnesses and infections and illness symptoms, illness affecting the respiratory system was the most common across all full-contact football-code sports (supplementary material 2-5). One study identified 13 cases of MRSA skin infections in 100 male American Football players during an in-season period of two months [20]. Contrary to this, within a matching sample size only 4 cases of MRSA skin infections were found over a full season (12 month period) of American Football (supplementary material two) [23]. Illness incidence could only be compared between studies that used the same incidence exposure measures. Heat illness incidence differed greatly across studies undertaken in American Football (4.19 [21] and 1.52 [22] per 1000 athlete exposures), however study duration also differed. Two studies in Australian Rules Football undertaken over the same time period found similar frequency of illness and infection, despite differing sample sizes [36, 45]. When illness and infection was monitored over a full season, frequency of illness was 67 cases in 45 athletes [26] (supplementary material three). One study in rugby league assessed illnesses and infections across one full season and found 45 reported illnesses in 32 athletes, with the most common symptoms affecting the respiratory system (runny nose, coughing and sore throat) [44] (supplementary material four). In rugby sevens, monitoring of the same competition over two consecutive years found that prevalence of illness increased in the second year in males (3.3% to 4.7%), but decreased in females (1.0% to 0.4%) [28] (supplementary material four). Across a full season, 148 illnesses were recorded in 30 male rugby union players [24]. During an 11 week pre-season period, 29 days were lost to eight illnesses; two were upper respiratory illness and 6 affected the gastrointestinal system (diarrhoea and vomiting) [33] (supplementary material five). During international competitions, the most commonly affected system was the respiratory system with an average illness incidence of 20.7 illnesses per 1000-player days [38-40]; seventy-four time-loss illnesses were recorded [38, 39].

The scores for the assessment of methodological quality, ranging from 15 to 21, out of 23, are available in supplementary material 6. All studies were found to be low [19, 20, 24-30, 32, 33, 35-39, 41, 42, 44, 45] to moderate [21-23, 31, 34, 40, 43, 46] risk of bias, with no studies found to be high risk.

Discussion

This is the first systematic review to summarise the type, incidence, prevalence and count of illnesses in elite full-contact football-code team sports. Following the screening process, 28 studies were identified that monitored illness within elite full-contact football-code team sports. There is a bias towards research in male athletes with only 31% of studies investigating female athletes; these were solely in rugby sevens [28, 35, 41]. Additionally, there is inconsistency across the literature regarding how illness data in full-contact football-code team sports are collected and reported; therefore, results could not be statistically pooled for meta-analysis.

This review identified that elite full-contact football-code team sport athletes are most affected by illness to the respiratory system. This supports findings from other sports across competition periods in both senior Paralympic summer and winter games [47, 48], youth Winter Olympic games [49] and aquatic sport world championships [50]. Previous reviews on illness in full-contact football-code team sports have solely focused on skin infections and blood-borne infections [7, 13], however the most commonly suffered illness is respiratory system illness, possibly caused by respiratory viruses.

Comparisons between full-contact football-codes for all illnesses and infections reported across pre-seasons showed that Australian rules football [36, 45] had approximately 20 – 75 illnesses per 100 players compared to 15 illnesses per 100 players in rugby union [33]. The change in environmental exposure due to pre-season training camps and associated travel, as well as greater pre-season external training load e.g. total running distance, may explain these differences. Australian rules football athletes cover between ~20,000-21,400 metres during a pre-season period [51] which greatly exceeds those covered in a rugby union case study (~9774-11,585 metres) [52]. High training loads have been shown to increase risk of illness [9, 53], therefore it is vital that athletes' training loads are appropriately monitored [9] to identify high risk times of potential illness, and for athletes' to be provided with greater support to manage illness risk. Furthermore, full-contact football-code sport athletes may be at increased risk of illness due to the unique demands of training and match-play. Frequent bouts of strenuous exercise, which are prevalent in full-contact football-code sport, are thought to increase risk of illness [9] and suppress immune system function [54]. Additionally, it could be hypothesised that the unique collision activity of full-contact football-code sports may further suppress immune function. Tackle and collision activity have been found to cause significant skeletal muscle damage [55] and increase total energy expenditure [6], potentially disrupting homeostasis and affecting immune function, however the theory of impact of collisions on immune function requires further investigation.

Across a full season, despite differing sample sizes, approximate URI count per player was greater in rugby union (4.1 URI per player) [24], compared to American Football (2.3 URI per player) [25]. Despite both methods using self-report, each study utilised varied definitions of illness, which could provide one explanation for the difference in results. Requirements for illnesses to be recorded included any URI symptoms being present for two or more days [24] as well as three specific symptoms (cough, runny nose, and nasal congestion) all being present for at least three days [25]. Additionally, over a full Australian rules football season, per player illness count was lower (1.5 illnesses per player) than both American Football [25] and rugby union [24], despite assessing all illnesses and infections [26]. This study utilised an amended version of the International Olympic Committee's (IOC) recommended definition for illness [9], documenting illness only when they required medical attention. Consistent reporting, monitoring tools and definitions for full-contact football-code sports would allow for greater and more informative comparison between results in future research.

When football-codes were compared across international competitions, rugby union [38, 39] had greater per player average illness compared to rugby sevens [28], despite varied competition durations (16 weeks and 31 weeks respectively). This difference could be explained by the style of competitions and number of tournaments assessed. The competition assessed in rugby union took place over 16 weeks as part of one tournament [38, 39]. Competitors travelled long distances, crossed multiple time-zones and additionally lived in close proximity with other players for prolonged periods of time, all which may increase risk of illness [7, 9, 56]. These details, and increased pathogen exposure, may have contributed to a greater average per player illness count compared to rugby sevens [28].

Most studies focused on illnesses that required medical attention or resulted in time-loss and did not acknowledge self-reported illness; this raises several issues. Firstly, previous research has outlined that self-report is a vital aspect of illness monitoring as not all athletes seek medical attention for the early warning signs of illness [9]. Secondly, it has been shown that athletes regularly continue to train and compete despite being ill, especially in the early phases of illness [57]. As these illnesses do not result in time-loss they would therefore not be recorded by standard illness surveillance systems [57]. Due to time restrictions, athletes may self-manage illnesses [18], also resulting in fewer illnesses being reported. Furthermore, despite previous consensus statements outlining the importance of consistent terms and definitions for research and clinical practice, only a handful of the studies used the IOC suggested definition for illness [9]. As definitions of illness varied across the studies, it would be beneficial to utilise standardised definitions of illness (from consensus statements [9, 58]) and for illness collection and reporting to be consistent across full-contact football-code sports. On the contrary, official diagnosis of infection via laboratory or clinician verification was only undertaken in 50% of all studies, therefore the true aetiology of reported illnesses is unknown. It is hypothesised that some reported respiratory system illnesses may mimic hay fever or allergy reactions, which may not be able to be differentiated from respiratory infections if not confirmed by laboratory or clinician assessment.

High quality illness surveillance is vital to support illness prevention within elite sport. Despite all studies meeting methodological quality assessment (supplementary material 6), this review highlights that many studies did not provide adequate descriptions of the athlete populations being studied [19-23, 29, 34, 35, 38-43, 46], including lack of information regarding total sample population, sex and basic descriptive data relating to study participants (i.e. age, stature and body mass). Furthermore, a meta-analysis was not performed as study designs were heterogeneous thus not able to be pooled. This shortcoming further supports the need for standardisation when monitoring illness within these sports.

A variety of exposure and illness incidence measures were used across the studies. These included per 1,000 player days [38-40], per 1,000 athlete exposures (AEs) [21, 22, 29], per 1,000 non-illness days [42], per 1,000 running hours [26] and per 10,000 athlete exposures [46]. Due to the differences in measures of exposure, incidence and prevalence could not be directly compared across the full-contact football-code sports based on the existing literature. Additionally, different methodological approaches alter the perception and interpretation of incidence rates, therefore matching exposure and incidence methods is required to better understand and compare the impact of illness within and between full-contact football-code sports. Other sports, including aquatic sports [59], have published consensus statements on the reporting of illness incidence, including suggestions of exposure measures and methods that can be used to report incidence. Furthermore, it may be important to also focus on the burden of illnesses, as well as incidence, to better understand the impact of illnesses on athletes [57].

This review highlights the lack of consensus of illness monitoring across full-contact football-code team sport literature. With varying definitions, incidence exposure calculations and poor participant characteristic details, limited high-quality surveillance is available. Previous research has identified high quality surveillance and data collection as an essential component to undertake effective and targeted illness prevention in athletes [18]. Early work of the Translating Research into Injury Prevention Practice (TRIPP) framework, identified surveillance as an essential first step towards prevention [60]. Improved data collection would provide greater understanding for practitioners, allowing development of intervention and prevention tools aimed at improving athlete care.

One strength of this study is the thorough search strategy used to identify eligible papers for this systematic review. A total of <5400 studies were screened using a strict inclusion criterion across a variety of full-contact football-code sports. This is the first study to systematically report the type, incidence, prevalence and count of illnesses across these sports. Previous research has used non-systematic methods [7, 13], which may have increased the risk of study selection bias. Within this systematic review, risk of bias was low to moderate for all included studies (supplementary material 6). One limitation is the lack of comparison between study findings. Due to the lack of consistency in illness reporting measures, statistical analysis could not take place as results could not be pooled. Consensus on illness reporting methodology for full-contact football-code sports and in research settings would allow for greater comparison between studies, and further improve the understanding on the impact of illness in these sports. Sport-specific data, that identifies body systems with increased illness frequency, can help support physicians and practitioners, allowing them to focus on the most common illnesses reported within these athletes.

Conclusion

Illness affecting the respiratory system is a common issue across American football, Australian rules football, rugby league, rugby sevens and rugby union. Greater understanding of the impact of illness in these sports is required. There is a distinct lack of consensus of illness monitoring methodology, with participant and study characteristics poorly reported across these sports. High-quality illness surveillance and data collection is an essential component to undertake effective and targeted illness prevention in athletes. Consistent collection and reporting of illness data would allow practitioners and medical staff to better support athletes during illness episodes and provide greater understanding of the impact of illness.

Practical Implications

- In line with illness monitoring across other sports, illness affecting the respiratory system is a common issue in full-contact football-code sports. Athletes, practitioners and medical support staff should focus on prevention and management of respiratory system illnesses which may impact players across the full playing season
- A distinct lack of consensus on illness monitoring methodology is present across full-contact football-code sports. High-quality illness surveillance and data collection is an essential component to undertake effective and targeted illness prevention in athletes
- Given the differences in methodology and reporting of illness across full-contact football-code sports, governing bodies and expert consensus groups should provide clarity and consensus on data collection to ensure improved illness prevention and athlete care can be provided

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References

1. Walsh NP. Nutrition and Athlete Immune Health: New Perspectives on an Old Paradigm. *Sports Med.* 2019; 49(Suppl 2):153-168.
2. Raysmith BP, Drew MK. Performance success or failure is influenced by weeks lost to injury and illness in elite Australian track and field athletes: A 5-year prospective study. *J. Sci. Med. Sport.* 2016; 19(10):778-783.
3. Palmer-Green D, Fuller C, Jaques R, Hunter G. The Injury/Illness Performance Project (IIPP): A Novel Epidemiological Approach for Recording the Consequences of Sports Injuries and Illnesses. *J Sports Med (Hindawi Publ Corp).* 2013; 2013:523974.
4. Tobe K, Matsuura K, Ogura T, et al. Horizontal transmission of hepatitis B virus among players of an American football team. *Arch. Intern. Med.* 2000; 160(16):2541-2545.
5. Dijkstra HP, Pollock N, Chakraverty R, Alonso JM. Managing the health of the elite athlete: a new integrated performance health management and coaching model. *Br. J. Sports Med.* 2014; 48(7):523-531.
6. Costello N, Deighton K, Preston T, et al. Collision activity during training increases total energy expenditure measured via doubly labelled water. *Eur. J. Appl. Physiol.* 2018; 118(6):1169-1177.
7. Stacey A, Atkins B. Infectious diseases in rugby players: incidence, treatment and prevention. *Sports Med.* 2000; 29(3):211-220.
8. Jimenez-Truque N, Saye EJ, Soper N, et al. Association Between Contact Sports and Colonization with Staphylococcus aureus in a Prospective Cohort of Collegiate Athletes. *Sports Med.* 2017; 47(5):1011-1019.
9. Schwellnus M, Soligard T, Alonso J-M, et al. How much is too much? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *Br. J. Sports Med.* 2016; 50(17):1043-1052.

10. Davies HD, Jackson MA, Rice SG, Committee On Infectious D, Council On Sports M, Fitness. Infectious Diseases Associated With Organized Sports and Outbreak Control. *Pediatrics.* 2017; 140(4):e20172477.

11. LaBelle MW, Knapik DM, Arbogast JW, et al. Infection Risk Reduction Program on Pathogens in High School and Collegiate Athletic Training Rooms. *Sports Health.* 2020; 12(1):51-57.

12. Nguyen DM, Mascola L, Brancoft E. Recurring methicillin-resistant Staphylococcus aureus infections in a football team. *Emerg. Infect. Dis.* 2005; 11(4):526-532.

13. Peterson AR, Nash E, Anderson BJ. Infectious Disease in Contact Sports. *Sports Health.* 2019; 11(1):47-58.

14. Gleeson M, Pyne DB. Respiratory inflammation and infections in high-performance athletes. *Immunol. Cell Biol.* 2016; 94(2):124-131.

15. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med.* 2009; 6(7):e1000100.

16. Swann C, Moran A, Piggott D. Defining elite athletes: Issues in the study of expert performance in sport psychology. *Psychol. Sport Exerc.* 2015; 16:3-14.

17. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J. Epidemiol. Community Health.* 1998; 52(6):377-384.

18. Bromley SJ, Drew MK, Talpey S, McIntosh AS, Finch CF. A systematic review of prospective epidemiological research into injury and illness in Olympic combat sport. *Br. J. Sports Med.* 2018; 52(1):8-16.

19. Archibald LK, Shapiro J, Pass A, Rand K, Southwick F. Methicillin-resistant Staphylococcus aureus infection in a college football team: risk factors outside the locker room and playing field. *Infect. Control Hosp. Epidemiol.* 2008; 29(5):450-453.

20. Begier EM, Frenette K, Barrett NL, et al. A high-morbidity outbreak of methicillin-resistant Staphylococcus aureus among players on a college football team, facilitated by cosmetic body shaving and turf burns. *Clin. Infect. Dis.* 2004; 39(10):1446-1453.
21. Cooper ER, Ferrara MS, Broglio SP. Exertional heat illness and environmental conditions during a single football season in the southeast. *J Athl Train.* 2006; 41(3):332-336.
22. Cooper ER, Ferrara MS, Casa DJ, et al. Exertional Heat Illness in American Football Players: When Is the Risk Greatest? *J Athl Train.* 2016; 51(8):593-600.
23. Creech CB, Saye E, McKenna BD, et al. One-year surveillance of methicillin-resistant Staphylococcus aureus nasal colonization and skin and soft tissue infections in collegiate athletes. *Arch. Pediatr. Adolesc. Med.* 2010; 164(7):615-620.
24. Cunniffe B, Griffiths H, Proctor W, Jones KP, Baker JS, Davies B. Illness monitoring in team sports using a Web-based training diary. *Clin. J. Sport Med.* 2009; 19(6):476-481.
25. Fahlman MM, Engels HJ. Mucosal IgA and URTI in American college football players: a year longitudinal study. *Med. Sci. Sports Exerc.* 2005; 37(3):374-380.
26. Fitzgerald D, Beckmans C, Joyce D, Mills K. The influence of sleep and training load on illness in nationally competitive male Australian Football athletes: A cohort study over one season. *J. Sci. Med. Sport.* 2019; 22(2):130-134.
27. Fowler PM, Duffield R, Lu D, Hickmans JA, Scott TJ. Effects of Long-Haul Transmeridian Travel on Subjective Jet-Lag and Self-Reported Sleep and Upper Respiratory Symptoms in Professional Rugby League Players. *Int. J. Sports Physiol. Perform.* 2016; 11(7):876-884.
28. Fuller CW, Taylor A, Raftery M. 2016 Rio Olympics: an epidemiological study of the men's and women's Rugby-7s tournaments. *Br. J. Sports Med.* 2017; 51(17):1272-1278.
29. Gamble ASD, Mountjoy ML, Bigg JL, Spriet LL. Implementation of Injury and Illness Surveillance Protocols in Varsity Athletes. *Clin. J. Sport Med.* 2018.
30. Greenwood M, Kreider RB, Greenwood L, Byars A. Cramping and Injury Incidence in Collegiate Football Players Are Reduced by Creatine Supplementation. *J Athl Train.* 2003; 38(3):216-219.

31. Greenwood M, Kreider RB, Melton C, et al. Creatine supplementation during college football training does not increase the incidence of cramping or injury. *Mol. Cell. Biochem.* 2003; 244(1-2):83-88.

32. Haywood BA, Black KE, Baker D, McGarvey J, Healey P, Brown RC. Probiotic supplementation reduces the duration and incidence of infections but not severity in elite rugby union players. *J. Sci. Med. Sport.* 2014; 17(4):356-360.

33. Jones C, Griffiths P, Towers P, Claxton J, Mellalieu SD. Pre-season injury and illness associations with perceptual wellness, neuromuscular fatigue, sleep and training load in elite rugby union. *Journal of Australian Strength & Conditioning.* 2018.

34. Kazakova SV, Hageman JC, Matava M, et al. A clone of methicillin-resistant Staphylococcus aureus among professional football players. *N. Engl. J. Med.* 2005; 352(5):468-475.

35. Nabhan D, Walden T, Street J, Linden H, Moreau B. Sports injury and illness epidemiology during the 2014 Youth Olympic Games: United States Olympic Team Surveillance. *Br. J. Sports Med.* 2016; 50(11):688-693.

36. Piggott B, Newton M, McGuigan M. The relationship between training load and incidence of injury and illness over a pre-season at an Australian Football League Club. *Journal of Australian Strength & Conditioning.* 2009; 17.

37. Pumpa KL, McKune AJ, Harnett J. A novel role of probiotics in improving host defence of elite rugby union athlete: A double blind randomised controlled trial. *J. Sci. Med. Sport.* 2019; 22(8):876-881.

38. Schwellnus M, Derman W, Page T, et al. Illness during the 2010 Super 14 Rugby Union tournament - a prospective study involving 22 676 player days. *Br. J. Sports Med.* 2012; 46(7):499-504.

39. Schwellnus MP, Derman WE, Jordaan E, et al. Elite athletes travelling to international destinations >5 time zone differences from their home country have a 2-3-fold increased risk of illness. *Br. J. Sports Med.* 2012; 46(11):816-821.

40. Schwellnus M, Janse van Rensburg C, Bayne H, et al. Team illness prevention strategy (TIPS) is associated with a 59% reduction in acute illness during the Super Rugby

tournament: a control–intervention study over 7 seasons involving 126 850 player days. *Br. J. Sports Med.* 2019:bjsports-2019-100775.

41. Soligard T, Steffen K, Palmer D, et al. Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: A prospective study of 11274 athletes from 207 countries. *Br. J. Sports Med.* 2017; 51(17):1265-1271.
42. Somerville V, Gill ND, Ross A, Braakhuis A. Upper respiratory illness in different tiers of rugby union. *Sport Sci Health.* 2019; 15(1):197-205.
43. Stacey AR, Endersby KE, Chan PC, Marples RR. An outbreak of methicillin resistant Staphylococcus aureus infection in a rugby football team. *Br. J. Sports Med.* 1998; 32(2):153-154.
44. Thornton HR, Delaney JA, Duthie GM, et al. Predicting Self-Reported Illness for Professional Team-Sport Athletes. *Int. J. Sports Physiol. Perform.* 2016; 11(4):543-550.
45. Veugelers KR, Young WB, Fahrner B, Harvey JT. Different methods of training load quantification and their relationship to injury and illness in elite Australian football. *J. Sci. Med. Sport.* 2016; 19(1):24-28.
46. Yeargin SW, Kerr ZY, Casa DJ, et al. Epidemiology of Exertional Heat Illnesses in Youth, High School, and College Football. *Med. Sci. Sports Exerc.* 2016; 48(8):1523-1529.
47. Derman W, Schwellnus MP, Jordaan E, et al. Sport, sex and age increase risk of illness at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. *Br. J. Sports Med.* 2018; 52(1):17-23.
48. Derman W, Schwellnus MP, Jordaan E, et al. The incidence and patterns of illness at the Sochi 2014 Winter Paralympic Games: a prospective cohort study of 6564 athlete days. *Br. J. Sports Med.* 2016; 50(17):1064-1068.
49. Steffen K, Moseid CH, Engebretsen L, et al. Sports injuries and illnesses in the Lillehammer 2016 Youth Olympic Winter Games. *Br. J. Sports Med.* 2017; 51(1):29-35.
50. Prien A, Mountjoy M, Miller J, et al. Injury and illness in aquatic sport: how high is the risk? A comparison of results from three FINA World Championships. *Br. J. Sports Med.* 2017; 51(4):277-282.

51. Ritchie D, Hopkins WG, Buchheit M, Cordy J, Bartlett JD. Quantification of Training and Competition Load Across a Season in an Elite Australian Football Club. *Int. J. Sports Physiol. Perform.* 2016; 11(4):474-479.

52. Bradley WJ, Cavanagh BP, Douglas W, Donovan TF, Morton JP, Close GL. Quantification of training load, energy intake, and physiological adaptations during a rugby preseason: a case study from an elite European rugby union squad. *J. Strength Cond. Res.* 2015; 29(2):534-544.

53. Malm C. Susceptibility to infections in elite athletes: the S-curve. *Scand. J. Med. Sci. Sports.* 2006; 16(1):4-6.

54. Walsh NP, Gleeson M, Shephard RJ, et al. Position statement part one: immune function and exercise. 2011.

55. McLellan CP, Lovell DI, Gass GC. Biochemical and Endocrine Responses to Impact and Collision During Elite Rugby League Match Play. *The Journal of Strength & Conditioning Research.* 2011; 25(6).

56. Keaney LC, Kilding AE, Merien F, Dulson DK. The impact of sport related stressors on immunity and illness risk in team-sport athletes. *J. Sci. Med. Sport.* 2018; 21(12):1192-1199.

57. Bahr R, Clarsen B, Ekstrand J. Why we should focus on the burden of injuries and illnesses, not just their incidence. *Br. J. Sports Med.* 2018; 52(16):1018-1021.

58. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). 2020; 54(7):372-389.

59. Mountjoy M, Junge A, Alonso JM, et al. Consensus statement on the methodology of injury and illness surveillance in FINA (aquatic sports). *Br. J. Sports Med.* 2016; 50(10):590-596.

60. Finch C. A new framework for research leading to sports injury prevention. *J. Sci. Med. Sport.* 2006; 9(1-2):3-9; discussion 10.

FIGURE LEGENDS

Figure 1 *Flow chart of selection process of eligible studies for qualitative synthesis*