When should an athlete retire or discontinue participating in contact or collision sports following sport-related concussion? A systematic review

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ABSTRACT

Objective To systematically review the scientific literature regarding factors to consider when providing advice or guidance to athletes about retirement from contact or collision sport following sport-related concussion (SRC), and to define contraindications to children/adolescent athletes entering or continuing with contact or collision sports after SRC.

Data sources Medline, Embase, SPORTSDiscus, APA PsycINFO, CINAHL and Cochrane Central Register of Controlled Trials were searched systematically.

Study eligibility criteria Studies were included if they were (1) original research, (2) reported on SRC as the primary source of injury, (3) evaluated the history, clinical assessment and/or investigation of findings that may preclude participation in sport and (4) evaluated mood disturbance and/or neurocognitive deficits, evidence of structural brain injury or risk factors for increased risk of subsequent SRC or prolonged recovery.

Results Of 4355 articles identified, 93 met the inclusion criteria. None of the included articles directly examined retirement and/or discontinuation from contact or collision sport. Included studies examined factors associated with increased risk of recurrent SRC or prolonged recovery following SRC. In general, these were low-quality cohort studies with heterogeneous results and moderate risk of bias. Higher number and/or severity of symptoms at presentation, sleep disturbance and symptom reproduction with Vestibular Ocular Motor Screen testing were associated with prolonged recovery and history of previous concussion was associated with a risk of further SRC.

Conclusion No evidence was identified to support the inclusion of any patient-specific, injury-specific or other factors (eg, imaging findings) as absolute indications for retirement or discontinued participation in contact or collision sport following SRC.

PROSPERO registration number CRD42022155121.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Advice from clinicians is commonly sought regarding decisions about when an athlete should retire or discontinue participating in contact or collision sport following sport-related concussion (SRC).

⇒ Decisions on when to cease participation in contact or collision sport are complex and multifaceted.

⇒ Historically, several opinion-based articles have been published, however, there are no evidence-based guidelines to facilitate decision-making by athletes with clinical input from healthcare providers.

WHAT THIS STUDY ADDS

⇒ No evidence was identified to support the inclusion of any patient-specific, injury-specific or other factors (eg, imaging findings) as absolute indications for retirement or discontinued participation in contact or collision sport.

⇒ Decisions regarding retirement or discontinuation from contact or collision sport in the context of SRC or repeated head trauma should involve clinicians with expertise in traumatic brain injury and sport and be individualised with consideration of psychosocial, injury-specific and sport-specific factors, any persisting symptoms and evolving neurocognitive concerns.

⇒ Clinicians should provide athletes (and their families or guardians) with the scientific facts and uncertainties of their condition, as well as the potential risks of returning to their previous sport and/or alternative activities with less chance of head trauma or SRC. The discussion should highlight the benefits of regular physical activity and incorporate the athlete's preferences, risk tolerance and capability to make an informed decision.

INTRODUCTION

Advice from clinicians is increasingly being sought regarding decisions about when an athlete should retire or discontinue participating in contact or collision sports in the context of sport-related concussion (SRC) and/or repeated head trauma. Discussions may be initiated by the clinician involved in the care of the athlete, the athletes themselves, other healthcare team members, coaches or administrators, or

family members/friends of the athlete. Increasingly, there is also media scrutiny of athletes who have sustained repeated concussions. The process may be prompted by the presence of factors including a history of multiple concussions, even in the absence of a recent injury, prolonged or persisting symptoms, decreasing scores on neurocognitive or other performance measures, evidence of changes on conventional structural neuroimaging or concern about changes in mood or behaviour, or long-term risk of mood disorders or neurodegenerative diseases that may be associated with SRC and/or repeated head trauma.[1–3]

Decisions on when to cease participation in contact or collision sports are typically complex and multifaceted. For instance, some athletes forego formal education to pursue a career in sport, and many high-performing or elite athletes tend to strongly identify with their athlete role, which are factors that can add to the complexity of discussions surrounding athletic retirement in the context of SRC.[4 5] Furthermore, mental health symptoms and disorders are often reported in elite athletes[6 7] and injury, as well as retirement, have been shown to be significant athlete-specific triggers.[8] It is important to consider incorporating a shared decision-making model that includes providing athletes with the scientific facts and uncertainties of their condition and considers the athlete's preferences and risk tolerance as well as psychological readiness to make a shared decision.[9–13]

Historically, several opinion-based articles have been published in the literature,[14–17] however, to date, there have been no definitive evidence-based guidelines to facilitate decision-making by athletes with clinical input from healthcare providers. The lack of clear evidence-based guidance may lead to an athlete who has been given the advice to cease participation in contact or collision sports, consulting several different doctors or 'doctor-shopping'. In addition, the decision may generate concern among clinicians about their medicolegal exposure when providing advice that may 'restrict the trade' of athletes, particularly in the case of professional athletes. It is also widely acknowledged that participation in exercise or physical activity confers a wide range of physical, cognitive and psychological health benefits[18–20] as well as financial rewards, particularly at the elite or professional level. In some individuals, these benefits may be mitigated or outweighed by potential risks related to SRC and/or repeated head trauma, including possible long-term effects on neurocognitive or brain health.

The aim of this study was to conduct a systematic review of the literature regarding the factors that should be considered when providing advice or guidance to athletes about retirement from contact or collision sport following SRC, and the contraindications to children/adolescent athletes entering or continuing with contact or collision sports.

METHODS

The review protocol was prospectively registered in the PROSPERO database for systematic reviews (protocol ID: CRD42022155121) and reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21]

The authors for this paper were selected based on research and/or clinical expertise in providing retirement recommendations following SRC, with broad representation across specialities, sports and countries.[22]

The search strategy was developed in Medline and used three main concepts: concussion, sports and retirement. Retirement was defined broadly for the search to capture all possible studies. The standardised search was developed for the concepts for concussion and sports for all the reviews and are described in the concussion consensus methods paper.[22] To help develop the search for retirement, all authors were invited to contribute keywords and reviewed the draft search. The draft search was created by the health sciences librarian (AH) and reviewed by all authors as well as peer-reviewed by another health sciences librarian (Zahra Premji). Suggestions for additional keywords from coauthors were incorporated as required. The search included both subject headings and keywords. Keywords were searched in the title, abstract and author-supplied keywords. When translating the search to other databases, keywords were similar, whereas subject headings were responsive to the indexing of the database. All searches were limited to 2001–March 2022. All search results were exported as RIS files and then uploaded to Covidence for deduplication and screening.

The following databases were searched: MEDLINE and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily (Ovid), Embase (Ovid), Cochrane Central Register of Controlled Trials (Ovid), CINAHL Plus with Full Text (EBSCO2022) and SPORTDiscus with Full Text (EBSCO). Searches were initially conducted October 2019, and top-up searches were run in March 2022. The complete search strategies for all databases are available in online supplemental file 1. The Medline search is annotated to provide information on search details.[23]

Articles that met the following criteria were eligible for inclusion: (1) original research (including randomised controlled trials, quasi-experimental designs, cohort, case–control, cross-sectional, case series, qualitative studies); (2) had SRC as the focus of the study (ie, >50% of the study population); (3) written in English; (4) peer-reviewed and (5) evaluated mood disturbance and/or neurocognitive deficits; decreased impact threshold for future concussion; evidence of structural brain injury (clinical, radiological, biomarker, etc); prolonged recovery from concussion (eg, persisting (>14 days in adults, >30 days in children) or permanent concussive symptoms); evaluated risk factors for prolonged recovery; evaluated lower threshold for concussion; evaluated history, clinical assessment and/or investigation findings that may preclude participation in sport. We defined children as 5–12 years and adolescents as 13–18 years.

An initial rapid screen was completed to exclude all articles that clearly did not meet inclusion criteria (eg, not SRC or <50% of the study population SRC, non-human studies, conference proceedings). Each title/abstract was screened by two authors independently. Inter-rater agreement was assessed prior to initiating the title and abstract screen with a threshold of 80% agreement. Discrepancies were resolved by a third, blinded reviewer. Full-text screening was completed by two authors independently and discrepancies were resolved by a third author.[22]

Two authors extracted data for each study using predesigned data extraction forms. Similarly, risk of bias (ROB) assessment was performed by two authors using the appropriate Scottish Intercollegiate Guidelines Network (https://www.sign.ac.uk/) critical appraisal notes and checklist. All articles were rated as low (acceptable or high quality) or high (unacceptable) ROB based on the assessment. Any discrepancies were discussed between reviewing authors until a consensus was reached. Where needed, the lead author acted to resolve conflicts. Strength of Recommendation Taxonomy (SORT) was used to assess the overall quality of the evidence.[24]

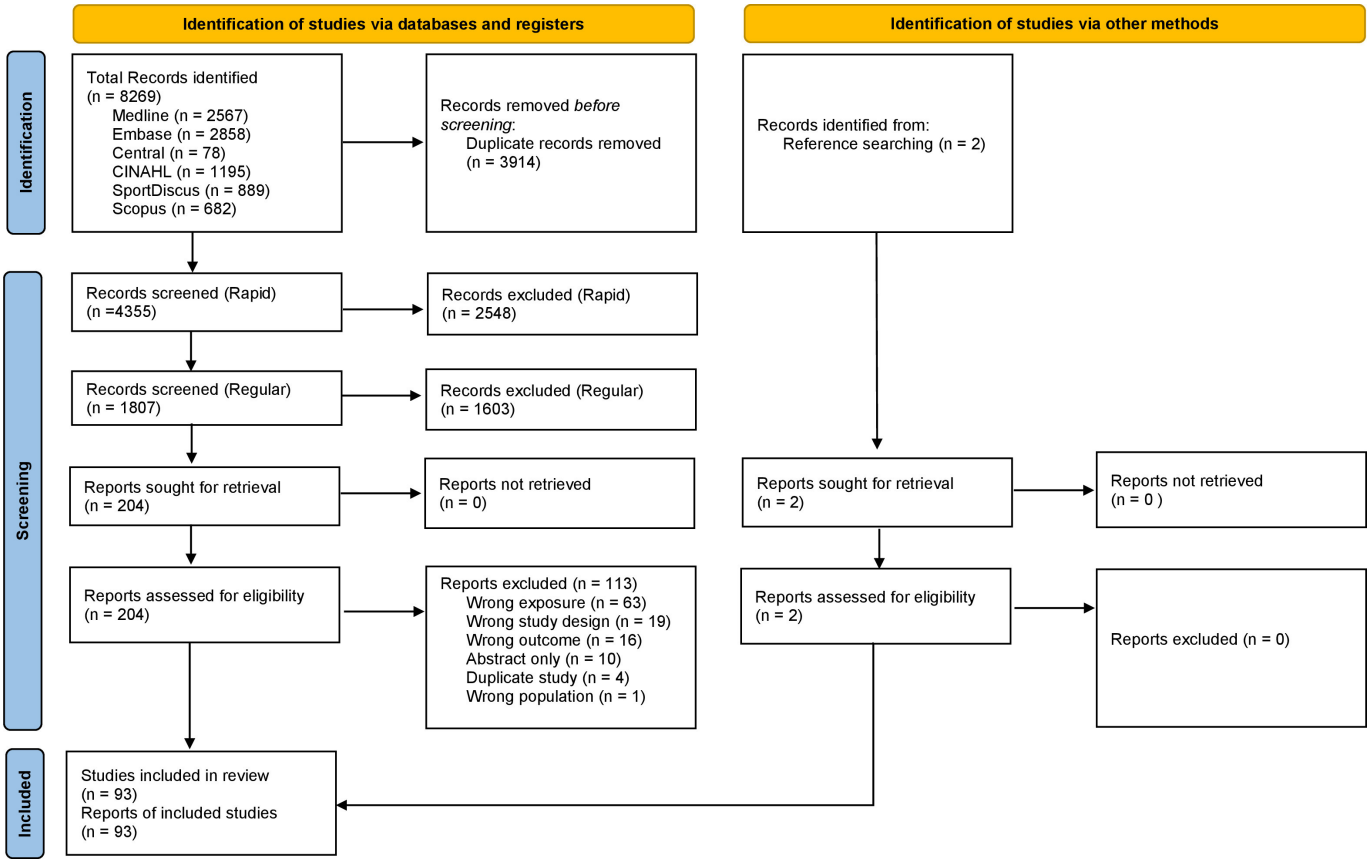

Figure 1 Modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram for new systematic reviews which included searches of databases and registers only.

Equity, diversity and inclusion statement

We included all eligible studies in the systematic review regardless of sample characteristics. Most studies included both males and females (85%) and no studies specifically mentioned the inclusion of parasport athletes. The authors of this review include both women and men, a variety of disciplines and persons of colour. The team lacks the perspectives of members of the lesbian, gay, bisexual, transgender, intersex, queer, asexual and other sexual or gender diverse (LGBTQI+) community, those in early career stages, and persons from low-income and middle-income geographical regions.

RESULTS

We found 8269 records in the database searches (figure 1). After the removal of duplicates, 4355 records were screened by title and abstract during rapid review, and 1807 records were screened by title and abstract to determine eligibility for inclusion. Following full-text review of 204 studies, 93 were included in the review.

The data extraction table and ROB assessments are summarised insupplementary online material. The studies included 38 prospective cohort studies, 42 retrospective cohort studies, 11 case–control studies and 2 cross-sectional studies. Sixteen studies included adults only (ie, aged >18 years), with the remainder of the studies including children and adolescent subjects (2 studies only included children ie, <12 years, 14 studies only included adolescent subjects, ie, aged 13 to <18 years).

Ten studies included male subjects only, 79 studies included both male and female subjects, and 4 studies did not report on the sex of their cohort.

None of the studies directly examined the issue of retirement and/or discontinuation from contact collision sports. All included studies assessed factors associated with prolonged recovery following SRC (summarised in table 1) and/or increased risk of concussion (summarised in table 2). Five studies were rated high quality, 75 of acceptable quality and 13 had a high (unacceptable) ROB (online supplemental file 2).

In general, the findings across studies were heterogeneous. The included studies differed widely in the clinical outcomes measured, the timing of assessments, definitions for 'prolonged symptoms' and whether conducted in specialty concussion clinics.

The most consistent results for factors associated with increased time to recovery and/or risk of persisting symptoms include longer time to presentation,[25–31] total number and/or severity of symptoms at initial presentation,[30 32–42] sleep disturbance[43–45] and symptom reproduction with Vestibular Ocular Motor Screen testing.[28 32 39 42 46–55]

Studies on plasma, salivary and/or cerebrospoinal fluid (CSF) biomarkers or advanced imaging biomarkers were limited in design, often with small cohorts of athletes.[56–64]

For studies assessing factors associated with an increased risk of concussion, the most consistent finding was that previous concussion was associated with a risk of further concussions.[40 41 65–68]

Given the lack of consistent and high-quality research, the variability in outcomes selected and lack of studies evaluating the specific question related to criteria for retirement, the strength of recommendation for criteria for retirement was rated as B ('Recommendation based on inconsistent or limited quality

Table 1 Factors associated with increased time to recovery/prolonged symptoms following SRC

Factor	Studies demonstrating increased risk	No association demonstrated
Age	32 33 83	84 85* 43* 25 34 35 86–88
Sex	25–27 33 36 37 65 89–92	32 84 85* 34 35 88 93 94* 38 95–98
Race		84 85* 88 97
Previous concussions	27 66 84 88 92 97 99–102*† 28 39	25 32–34 38 67 68 87 93 95 98 103–107
Premorbid headache syndrome/migraines	33 39 97 108	29 32 86 92 95 106
Mental health/mood disorders (anxiety/depression)	46 88 109–111	26 32 38 86 93 97 112 113
Learning disability		33 84 85* 26 38 46 87 93 97 106
ADHD	84 92	26 33 46 87 88 93 97 103 106 107
Continued participation in sport	90 93 114	30
Longer time from injury to receiving medical attention	25–31	
Total no/severity of symptoms at initial assessment	30 32–42 115	86 98
Post-traumatic headache/migraines	33 85* 26 91 116	38 106
Specific symptom clusters	37 39 87 88 91 95 98 117	
Worsening symptoms from injury to clinic presentation	91	
Fear of pain questionnaire score	32	
Alcohol, tobacco or marijuana use since injury	97	
Low resilience score (Connor-Davidson Resilience Scale)	118	
Dizziness	46 106	
Difficulty concentrating	85*	
Difficulty remembering		85*
Amnesia	85* 34 68	26 35 88 92 95 106
Loss of consciousness	85* 34 36	26 35 46 68 88 92 95 106
Sleep disturbance	43–45	
Orthostatic intolerance	28	
Presence of vestibular/oculomotor deficits	28 32 39 42 46–53 54* 55	
Presence of convergence insufficiency	55 119	46
Tandem gait deficits	28 48 120	
Presence of neuro-psychological deficits on computerised screening tests (eg, ImPACT)	26 41 42 121*	35
Exercise tolerance in subacute phase of recovery	122	
Dual-task transverse plane movement and lateral step variability	120	
'5P clinical risk score'	123	
(GT)n Promoter Polymorphism	124	
Plasma t-tau	56	
Salivary microRNA biomarkers	57	
CSF biomarkers	125	
Higher perceived parental stress	113	
Structural neuroimaging (MRI)	126* † 127†	128
Advanced neuroimaging	58 129* 59 60–62* 63	
Functional near infra-red spectroscopy (haemodynamic response)	130†	

*High (unacceptable) risk of bias.
†Associated with long-term risk/changes.
ADHD, attention-deficit hyperactivity disorder; CSF, cerebrospinal fluid; ImPACT, immediate post-concusssion assessment and cognitive testing; SRC, sport-related concussion.

patient-oriented evidence'") or C ('Recommendation based on consensus, usual practice, opinion, disease-oriented evidence, case series for studies of diagnosis, treatment, prevention or screening').[24]

Table 2 Factors associated with risk of concussion

Factor	Studies demonstrating increased risk	No association demonstrated
Sex	40	65
Previous concussions	40 41 65–68	
Level of play		65
Mental health disorders (anxiety/depression)	109	
Genetics	131	132*

*High (unacceptable) risk of bias.

DISCUSSION

There was no evidence identified by this systematic review to support the inclusion of any patient-specific, injury-specific or other factors (eg, imaging findings) as absolute indications for retirement or discontinued participation in contact or collision sports.

When considering our research questions, we included a broad search of factors that may lead to an increased risk of repeat concussions and/or a significant risk of adverse health outcomes if the individual was exposed to further head trauma and/or SRC. The factors evaluated in the included studies investigated common clinical presentations such as prolonged or persisting postconcussion symptoms, neurological or cognitive deficits, persistent mood or behavioural disturbance, decreased impact threshold for future concussion and radiological evidence of structural brain injury (some of which may be detected incidentally and may not be related to SRC).

The results revealed that several factors may be associated with either an increased risk of recurrent SRC or of prolonged or persisting symptoms following SRC (see tables 1 and 2). Greater time from injury to receiving medical attention has been shown to be associated with longer recovery.[25–31] From a secondary prevention standpoint, recognising the importance of early assessment and management of SRC may result in reduced risk of persisting symptoms. Similarly, athletes with initial high symptom burden[29] and children/adolescents with higher risk scores[69] could be screened and directed for evidence-informed interventions in the early period following SRC, which may reduce the risk of persisting symptoms. However, the results were inconsistent across studies, which may be due in part to the heterogeneous populations, study designs and outcome measures used. Furthermore, the quality and quantity of the data were low, with a high ROB identified in many of the studies (see online supplemental file 2).

Studies examining factors such as age, sex, prior concussions, attention-deficit hyperactivity disorder (ADHD) or learning disabilities and prior history of mood disorders or migraines demonstrated variable outcomes. This is likely due to variability in study quality, exposure and outcomes evaluated. Many studies sampled patients from specialty clinics which raises the threat of selection bias, where the participants included in the studies may represent a more severe sample and thus more likely to have suffered from persistent symptoms or functional limitations that may overestimate the relationship between exposure and outcome. Furthermore, many studies conducted univariant analyses and failed to take into consideration important potential confounding factors. Thus, future high-quality incident cohort studies (ie, following groups of athletes forward over time) are needed; until then, the answers to our questions remain largely unanswered.

Given the evolving nature of the evidence regarding SRC and ongoing concerns related to potential long-term adverse psychological and/or neurocognitive outcomes, it is expected that clinicians will increasingly be faced with questions regarding retirement or discontinuation of contact or collision sports. We suggest a pragmatic approach based on the collective clinical and research experience of the author group and guided by the systematic review. The advice provided is not intended as a clinical practice protocol/directive or legal standard of care and should not be interpreted as such, but rather as a set of general principles to be used by clinicians to provide structure to the complex and multifaceted decision-making process regarding retirement or discontinuation from contact or collision sports in the context of SRC or repeated head trauma.

Traditionally in sports medicine, return to play or return to sports decisions following injury rely on the identification of 'absolute' contraindications that may signify an unacceptable risk to return, the consideration of 'relative' contraindications that may be associated with an increased risk of poor outcomes, and the assessment of other important individual factors such as athlete knowledge, values, priorities, risk tolerance, etc.

There are several factors that have been suggested in the literature as indications for not returning to contact or collision sports following SRC.[14–17] These are summarised in box 1.

Based on the results of the systematic review, there is no evidence to support any one factor being an 'absolute' contraindication to an athlete being able to continue participation in a contact or collision sport. Given the current limitations in knowledge, it is important that clinicians do not overindex any specific anecdotal guidelines or rely on any one clinical factor when advising athletes about when to retire or discontinue participation in contact or collision sports. Rather, an individualised and collaborative approach to shared decision-making is recommended.

Box 1 Factors suggested as possible indications for not returning to contact sport

Persisting or prolonged
1. Symptoms after concussion.
2. Neurological abnormalities on physical examination.
3. Deficits on neuropsychological testing, despite time away from contact or collision sports, and compliance with prescribed treatments or interventions.

Increasing symptom severity and/or duration with repeat concussions.

Concussions precipitated by lower threshold impacts.

Structural abnormalities identified on conventional neuroimaging that may be associated with an increased risk of poor outcomes with future head impact and require neurosurgical assessment and management.

Athletes with persisting symptoms, neurological abnormalities and/or neurocognitive deficits are typically not considered to be cleared for return to contact or collision sports. Given the non-specific nature of the symptoms, and considerable overlap with other syndromes (eg, mood disorders, post-traumatic headaches/migraines), it is essential to identify and treat co-existent pathology that may respond positively to treatment.[70 71] Consequently, it is recommended that clinicians with experience in SRC be involved in the assessment and treatment of the athlete before discussions regarding retirement from sport are initiated. Furthermore, in these instances, a cautious process-oriented approach to decision-making is suggested, where it may be more prudent to restrict contact or collision sport for a prolonged period (eg, one season) before reassessment and reconsideration of retirement. Obviously, in some cases, the athlete may choose not to return to contact or collision sports given the impact that symptoms may have on work, education and quality of life.

In this systematic review, we identified several factors that may be associated with an increased risk of recurrent SRC, prolonged or persisting symptoms or long-term adverse sequelae (tables 1 and 2). These form the basis of important clinical factors that should be considered as part of a comprehensive assessment in the multifaceted decision-making process regarding retirement or discontinuation from contact or collision sports in the context of SRC or repeated head trauma.

Based on the results of this systematic review and the collective experience of the author group, it is suggested that the following issues are also considered when discussing ongoing participation in contact or collision sport.

1. History of prior concussion, including frequency (decreased interval) between concussions, symptom burden and severity at the time of injury, duration of clinical recovery from previous concussions and increasing severity with each successive concussion or minimal impact producing concussion.
2. Sport-specific factors, including, type of sport played, years played, position and playing style. Inherent to this discussion is a detailed understanding of concussion risk as well as the head impact dynamics (ie, the number and magnitude of acceleration, deceleration and rotational forces) commonly observed in the sport and the implications these may have to return the athlete to the risks associated with that sport. The level of play is also important. Financial benefits exist

in professional sports, which may add to the complexities of the decision-making process, as well as the legal implications for the healthcare provider who may be concerned about restriction of employment or trade. Furthermore, some sports have their own specific regulations regarding clearance for participation (eg, retinal detachment in boxing).

3. Psychological factors including values, athletic identity, risk tolerance and readiness or confidence to return to contact or collision sports.[72 73]
4. The child or adolescent athlete. Brain development continues throughout childhood and into young adulthood. In children, progressing to the next age group level in contact or collision sports, especially prepubescent to postpubescent children may pose additional risks, especially given the variable age of growth and likelihood of mismatch of size and strength of players in the competition. Similarly, adolescent athletes who may be progressing to higher levels of competition, including participation in elite pathway programmes and/or open-age competitions, may pose higher risks with increased training loads, players of a larger size and/or higher velocity of impacts. The cognitively immature child/adolescent athlete may not yet be capable of adequately understanding the relative risks and benefits of participating in contact or collision sports, and parents/guardians may not be unanimous in their recommendations, influenced by multiple factors including cultural and socioeconomic background,[74] expectations for the child's future professional sports capabilities, vicarious benefits from the child's sporting achievements and parental anxieties. It is also imperative to appreciate that the priorities in children are cognitive and emotional development and physical maturation. Therefore, if repeat concussions in an individual child limit the ability to return to school and develop appropriately, restrictions on returning to contact or collision sports must be considered. However, considering the important health benefits of implementing a physically active lifestyle in youth,[19 20] it is equally critical that any child or adolescent restricted from participating in contact or collision sports be encouraged to participate in other non-contact physical or sporting activities.
5. Geographical variations. Various legal and cultural frameworks exist in different countries and territories that may impact decisions regarding retiring or discontinuing participation in contact or collision sports.
6. Para-athlete. Factors can be even more complex in the assessment of para-sport athletes. Athletic identity is an important consideration as participation in sports may present an opportunity to transcend the bias and stigma the individuals may experience when going about their daily lives. The presence of a neurological finding would not necessarily exclude someone from engaging in sport, but specific circumstances (eg, seizure disorder in cerebral palsy or for those with neuromuscular conditions and the impact on sport), should be medically cleared prior to participation in sport.

The assessment should be individualised and involve clinicians with expertise in traumatic brain injury and sport, and frequently and preferably will include an independent multi-disciplinary team. The ensuing shared decision-making process should:

1. Include a discussion that considers the benefits of participation in physical activity including important effects on physical, psychological, social and cognitive well-being weighed against the potential long-term risks that may be associated with concussion and/or exposure to repeated head trauma.[75] Removal from sports even temporarily can exacerbate psychological health issues and providers need to be keenly aware to balance protection with the potential harms of removal. Given the positive benefits of exercise on health, care must be taken to avoid restricting all physical activity. Exercise and physical activity are critical in the prevention and management of many chronic diseases.[76–78] Any athlete who ultimately retires from contact or collision sports should be encouraged to continue non-contact or low-contact physical activity and the benefits explained.
2. Address the key concerns and correct any misconceptions that the athlete or their family, caregivers, or guardians, in the case of athletes under the age of legal consent, may have.
3. Use language that is appropriate for the health literacy of the individuals based on multiple factors, including their level of education and culture, to reduce the risk that the information is misinterpreted.
4. The assessment should be carefully documented, as with all aspects of medical care and decision-making.

In many instances, the clinician will help weigh the risks versus benefits and provide their opinion to the athlete, based on their best clinical judgement. Consequently, the advice should be provided by someone with expertise in concussion and head trauma and encompass input by clinicians from disciplines relevant to the athlete's presentation who are familiar with the sport-specific elements of any risk.

Alternatively, it has been suggested that the clinician should not provide specific guidance, but rather provide enough information for the athlete to make an informed decision. Turner *et al* suggested that 'the choice to return to play after a concussion or mild TBI injury is the athlete's decision once they have (1) recovered from their injury and have the legal capacity to make an informed decision; (2) been medically assessed and (3) been informed of any possible long-term risks in a language that they can understand'.[79]

Retirement or discontinuation of a sports career due to injury has potentially life-altering consequences, irrespective of the level of play, and has been associated with an increased risk for mental health symptoms and disorders.[6 8 80] It is critical that any athlete in this situation be afforded adequate psychological support and follow-up.[81]

Medical ethical and legal considerations

It is beyond the scope of this paper to provide a comprehensive review of the medico-legal issues associated with an athlete's decision to retire. However, consideration of the ethical and legal duties owed to athletes by medical staff in providing medical advice in the best interests of the athlete patient is an important part of such a process. Different jurisdictions may have their own legislation and case law, and different sports governing bodies may impose their own regulations or guidelines in relation to the management of concussion in their sport. Broadly from a legal perspective, in advising an athlete, it is important that medical staff:

- Make the athlete aware of the role(s) they play in the athlete's care, stating clearly if they have or foresee any potential or actual conflicts of interest affecting the decision that might compound informed decision-making by the athlete.
- Make best efforts to ensure the athlete is free from coercion or undue influence.
- Take all reasonable steps to ensure the athlete has the capacity to make an informed decision.
- Make best efforts to ensure that all parties to the discussion are aware of and respect patient confidentiality.

- Have understood the athlete patient's own conception of their best interest and informed the athlete of the risks that may be associated with continuing to participate, based on current knowledge of the relevant literature/research.
- Use terms and language the athlete understands.
- Offer the athlete the opportunity to ask medically relevant questions.
- Respond as best they reasonably can to more holistic questions and discuss concerns raised by the athlete.
- Understand and respect that, ultimately, it is the competent adult athlete's decision whether to retire.
- Consider the use of a cool-off period to allow time for further reflection and consultation where appropriate.
- Make and retain some form of written record that documents the process.

Specific issues arise with child and adolescent athletes. While legislation including the defined age of a 'child' may vary across different jurisdictions, in general terms, a parent or guardian must consent to medical treatment of a child. Even under these conditions, however, it is good practice to seek the assent of the child. Many jurisdictions recognise that 'mature minors' may be competent to consent or refuse treatment if they can reasonably understand the information set provided and are not subject to undue influence. Nevertheless, medical staff should be aware that for more significant medical decisions, such as return to play following SRC, it would be prudent to involve a parent/guardian in the discussion and ensure the informed consent of a parent/guardian is obtained.[79]

Further considerations and future research

This systematic review has revealed limited scientific evidence to specifically direct decisions regarding retirement from or participation in contact or collision sport.

To allow us to better inform such decisions future research should focus on

- Improved understanding of potential long-term risks related to concussion and repeated head trauma.
- Robust, clinically relevant biomarkers of brain recovery.
- Identification of genetic risk factors for poor long-term outcomes.
- Understanding of head impact exposure and concussion risk of various sports. This should include all levels in which the game is played as well as cover all competitors (including representation of ethnicity, sociocultural factors, sex and gender, age, disability, level of competition).

Ideally, studies should be prospective cohort designs, which include measurement of factors that may have an impact on outcome including age, sex, sport, culture, genetics, previous injury, coexisting medical conditions, playing conditions (eg, air quality) and socioeconomic status. Also, studies often lack objective and valid measures of exposure to sport and frequently rely on self-reports of exposure or years played. To date, most funding is allotted for research that involves shorter durations (ie, 1–5 year studies) and does not enable prospective follow-up of athletes over time, thus limiting our understanding of the potential factors that are important to consider in decisions related to retirement. The terminal endpoint of most studies is 'return to play clearance' where players would return to the at-risk cohort, however, the short duration of studies precludes longer evaluation of outcomes. In other fields, prospective cohort studies with long-term follow-up have significantly advanced knowledge (eg, Framingham heart study).

Therefore, future studies should investigate factors associated with unfavourable outcomes after return to play such as early recurrence of concussion or severe injuries leading to chronic impairments and disabilities.

It is also incumbent on individual sporting bodies, associations and federations to implement evidence-based rule changes and regulations that assist in reducing the risk of concussion and exposure to repeated head impacts/accelerations.[82] Such regulations may, in some circumstances, mandate that the athlete does not return to a particular sport (eg, boxing), when the risks to the individual athlete (based on expert medical opinion) are considered too great.

Review limitations

The main limitation of our systematic review was the large degree of heterogeneity and low methodological quality of the included studies. Furthermore, we only included studies that evaluated the investigation or treatment of SRC. Finally, there was an inherent limitation related to publication bias.

Key recommendations (box)

1. Decisions regarding retirement or discontinuation from contact or collision sports in the context of SRC or repeated head trauma are complex and multifaceted and should, therefore, involve clinicians with expertise in traumatic brain injury and sport, and preferably include a multidisciplinary team (SORT C).
2. The decision-making process should be individualised and incorporate a comprehensive clinical history and physical examination, sequential clinical evaluation and neuroimaging (when clinically indicated). (SORT C) The assessment should include consideration of psychosocial factors (eg, values, identity, risk tolerance, psychological readiness), injury-specific factors (eg, history of prior concussions including number, worsening postconcussive symptoms with subsequent concussions, lower threshold for concussions), sport-specific factors (eg, type of sport, level played),and any persisting symptoms and/or neurocognitive concerns (SORT C).
3. In athletes with persisting or prolonged postconcussion symptoms, neurological abnormalities and/or neurocognitive deficits, it is essential to identify and treat and pre-existing, coexisting or resultant pathology (eg, mood disorders, post-traumatic headaches/migraines) (SORT B).
4. The clinician should make the athlete aware of the role(s) they play in the athlete's care, stating clearly if they have or foresee any potential or actual conflicts of interest affecting the decision that might compound informed decision-making by the athlete (SORT C).
5. The discussion should provide athletes with the scientific facts and uncertainties of their condition as well as the potential risks associated with returning to their previous sport and/or alternative physical activities with less chance of head trauma or SRC. It should highlight the benefits of regular physical activity and incorporate the athlete's preferences, risk tolerance and capability to make an informed decision. The discussion should be communicated in a manner that considers the athlete's language preference, education and health literacy, and include others stakeholders (eg, parents, family) as indicated. The discussion, including the athlete's understanding of what was communicated, should be carefully documented in the medical records (SORT C).
6. In the child or adolescent athlete, the primary concerns are return to school and maintaining healthy levels of physical

activity. This often requires a multidisciplinary process that includes the child/adolescent, parent/caregivers, healthcare providers, school leadership and teachers in the discussions (SORT C).
7. Given its positive benefits on health, care must be taken to avoid restricting all physical activity. Athletes who retire from contact or collision sport should be encouraged to continue non-contact or low-contact physical activity (as medically tolerated) and have the benefits of such engagement explained (SORT B).
8. Further high-quality longitudinal research is needed to inform a risk–benefit model to facilitate informed, individualised decisions about retirement or discontinuation from contact or collision sport.
9. Input and counsel from healthcare professionals knowledgeable regarding brain injury can be helpful in making decisions about retirement. The ultimate choice is one of an informed decision made by the athlete and/or their guardian or parent (SORT C).

CONCLUSION

There was no evidence identified by this systematic review to support the inclusion of any patient-specific, injury-specific or other factors (eg, imaging findings) as absolute indications for retirement or discontinued participation in contact or collision sports.

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