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REVIEW

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What are the evidence-based medical management approaches for the concussed youth athlete? A scoping review

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ABSTRACT

Background: Concussion management in youth sport relies on the experience of adults pitch-side as to injury recognition, removal, and management decisions. Little consensus exists on the consistency of pitch-side and medical pathway management approaches.
Objectives: A scoping review was completed to identify and synthesise primary research as to the management of the concussed youth athlete.
Methods: A systematic search was completed in Medline, CINAHL, PubMed, SPORTDiscus, OVID emcare, Web of Science, ScienceDirect, and Cochrane Library databases and Google Scholar from inception to 1st March 2025 according to PRISMA-ScR guidelines. Primary research studies that provided outcome data on management approaches for concussed youth athletes at all stages post-injury were included. Articles were synthesised and reported in themes.
Results: 36 studies were included and four themes identified: Exercise, activity, and neuromuscular training interventions (n = 14), Pitch-side, sub-acute management and monitoring (n = 6), Novel treatment interventions (n = 5), and individual management in specific populations (n = 11).
Conclusion: Published primary research for concussed youth athlete management approaches with outcome data supports early activity recommendations and sub-threshold exercise programmes. Few data exist for alternative management approaches. Case reports/ series saturated this review, with limited generalisable data reported on. Further transparency on concussion injury reporting and management, with outcome data, is warranted.

Keywords: Adolescent, Brain concussion, Brain injuries, Patient care management, Rehabilitation, Sports

What is already known about this topic?

- *Concussion management approaches are based on consensus group agreements and recommendations. Previous reviews provide rationale for generalised management approaches for injured athletes. Recommended approaches often require resources and adequate training, limiting implementation.*

What this study adds?

- *This study reviews the primary data sources that currently stand as rationale for concussion injury medical management approaches, and highlights the lack of such sources, particularly from populations outside of the United States of America (USA)/ Canada.*

Introduction

Participation in sport is encouraged by schools, governments, and healthcare professionals for the physical, mental, and social benefits it can provide. Despite this, sports with an increased incidence of head contact injuries and sub-concussive forces could negatively impact long-term brain health (1,2). Concussions or mild traumatic brain injuries (mTBI) are common within the youth athletic and sporting populations (3). The term concussion is well-used, however, poorly articulated. It broadly relates to the cluster of symptoms that results following a mild brain injury (4). McRory et al. defined a sports-related concussion as “a traumatic brain injury that is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces” (4). Many authors use the term ‘concussion’ to categorise neurological deficits following head trauma as a result of biomechanical forces (5). Whilst a traumatic brain injury (TBI) is often diagnosed using imaging such as magnetic resonance

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imaging (MRI) or computerised tomography (CT), the use of imaging for a concussed patient will often show no obvious structural change to the brain (6). The lack of a definitive clinical or diagnostic test for concussion proves challenging for medical professionals, such as pitch-side physiotherapists, when deciding when to remove athletes from play and in attempts to treat the concussion. Where initial mild head injuries are missed during play, in rare circumstances, a further brain insult can result in second impact syndrome, with fatal consequences for individuals (7).

The overall global annual prevalence of concussions in all age groups is estimated to be more than 6 per 1000 people (8). Data from the United States of America (USA) suggests that 1 in 5 adolescents have sustained a concussion (9). Around 1-in-3 concussions are induced by a sports-based mechanism, and in Canada, contact sports are the leading cause of concussion in young people (10,11). Concussion prevalence and injury susceptibility may be increased for the youth athlete due to differing pathophysiological responses in the developing brain (12-14). Youth female athletes are at greater risk of sustaining a concussion, potentially due to a reduced biomechanical threshold tolerance for impacts (15). However, female players are more likely to report a concussive injury to coaches, and there is preliminary evidence that the symptom burden is higher in youth female athletes (15,16).

In community youth sport settings, coaches and parents often lead the identification and management of sports injuries. If a grass-roots sports team is well-resourced, it may have additional first-aid staff or physiotherapy cover. In the United Kingdom (UK), the Government published its concussion guidance for grassroots sport in April 2023 (17), and other countries have followed suit (18,19). However, literature suggests there is a lack of knowledge of the Sports Scotland guidance publication from 2018, *"If in doubt, sit them out"*, amongst football coaches (20,21). This highlights the challenges of the translation of guidance documents to effective pitch-side management strategies in the community game. Despite increased resources, even in professional sports, there remain concerns over under-reporting, misdiagnosis, and poor pitch-side management of concussions (22). Events as recent as the 2022 Fédération Internationale de Football Association (FIFA) World Cup have highlighted that even the most prestigious sporting tournaments can fall short in terms of concussion protocol standards (23). Despite advances in public health messaging and formalised guidance and return-to-play protocols being published, both immediate and subsequent management of the concussed youth requires scientific data to support approaches taken. Empirical evidence has guided many of the recent publications on concussion management approaches, yet there remains no current available Scottish Intercollegiate Guidelines Network (SIGN) or National Institute for Health and Care Excellence (NICE) publications on youth concussion. Concussion guidelines have been developed from the consensus statement from the 5th and 6th international concussion conferences in Berlin, 2016, and Amsterdam, 2022 (4,24). Whilst the consensus statement acknowledges the barriers and challenges of sideline youth sport concussion management, often due to a lack of availability of medical staff, there is limited discussion of the data-driven approaches to support and rehabilitate a concussed youth. Piedade et al. reported on the poor standardisation of concussion management across age groups, and also the lack of high-quality evidence to guide practice (25). This lack of data is concerning as evidence-based practice is dependent on appropriate information as to comparative management to support treatment algorithms and best practice rehabilitation choices. Physiotherapists, working with concussed youth athletes pitch-side, or indeed in primary or secondary care settings, require data to inform their treatment and management approaches. Therefore, the aim of this study was to complete a systematic search of published primary research literature on the medical management, rehabilitation approaches, and outcome data. For the concussed youth athlete across all stages of injury management.

Methods

A scoping review of the literature was undertaken in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) guidelines (26). Our protocol and search strategy were pre-published on the open science framework website – CrossRef This protocol included our study design.

Authorship group statement

Our author team consisted of three men and one woman, which was the makeup of the PhD supervisory team. All authors reside in the United Kingdom, and two authors were from Scotland, one from Chicago in the United States, and one from the Netherlands. The paper was led by the main author, who is a PhD student and supported by the supervisory team. All team members are chartered physiotherapists.

Information sources and search strategy

We applied the population, concept, and context (PCC) criteria to inform our search strategy that aimed to find primary research articles that reported outcome data on medical management approaches for the concussed youth athlete worldwide. The search strategy was devised in conjunction with a specialist librarian and an electronic search of the following databases was conducted from inception to 1st March 2025 in Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, SPORTDiscus, Cochrane Library, MEDical Literature Analysis and Retrieval System Online (MEDLINE), Ovid Emcare, Web of Science and the Cochrane Library. Boolean operators and MeSH terms were employed in the searches as detailed in the supplemental data. A hand search of subject-relevant journals, using the search term 'concussion', was also completed. Keywords were identified from initial database searches and screening. Such chosen keywords were used in a free text search of Google Scholar and further searches of grey literature. A simplified search strategy, using eight subject heading keywords only, was completed in ScienceDirect and Ovid emcare due to database limiters, using such chosen keywords. Reference lists of included manuscripts were hand-searched for additional information sources. We applied an English language restriction, but no other filters to the search.

Eligibility Criteria and Study Selection

Due to the nature of our research objectives, all primary data capture study types were considered for inclusion, provided they were published as peer-reviewed research articles and reported on outcome data for pitch-side, medical, and rehabilitative management approaches for the concussed youth athlete. We limited our search to participants up to and including the age of 19 years, which is the World Health Organization's end range age for adolescents (27). This focused our review specifically on adolescent and child athletes involved in pre-college and pre-university level sport.

We employed a broad definition of concussion and included terminology synonymous with 'concussion' for the search. All stages of sport-related concussion management were considered, including: identification and initial assessment; primary and secondary care management; and home-care management. Studies reporting on more serious forms of traumatic brain injuries (moderate or severe TBIs) were excluded, due to differing management approaches and alternative diagnoses. All levels of sporting participation were considered for this study. We excluded expert opinion or narrative articles, and excluded material that was not available as a full-text publication, such as conference abstracts. Studies relating to concussion epidemiology and diagnostics were excluded. We also excluded articles that reported standardised hospital pathway data, as these articles did not provide discernible information on interventional management approaches and their outcomes. Manuscripts conducting retrospective analyses were excluded if they were reporting on secondary data that was not collected by the study team for their own sole purpose of analysis. We also excluded articles that included participants who had not sustained a sports-related concussion (SRC).

A three-part screening strategy was employed to identify relevant articles. Covidence systematic review management software was used to process database results and screen articles (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia). Two investigators independently carried out the searches and screened by title using the online Covidence software platform (TM and SV]. Abstracts were reviewed independently by the same two investigators, and a consensus was reached for full text inclusion. In the event of disagreement or doubt, manuscripts were included for full text review. Full texts were reviewed by the same two reviewers independently, and the final selection was agreed upon by consensus with a third independent reviewer.

Data extraction and synthesis

Data extraction forms were created, and two researchers [TM and SV] independently extracted the data from included articles. The following characteristics of each study were extracted to a bespoke excel database and data was extracted as per our published protocol [Author/s and Year of publication, geographical location, study design, level of evidence (28), study aims, population and sample size (Including number of male and female participants, methods, intervention type and comparator, theme, outcomes and measurement and results)]. The results were synthesised and pooled by themes and sub-themes.

Results

The search generated 11640 articles (Medline: 4038; CINAHL: 1794; Web of Science: 1982; PubMed: 1772; OVID Emcare: 436; Science Direct: 455; Cochrane Library: 446; SPORTDiscus: 717). Following the removal of duplicates, 5410studies were evaluated against the eligibility criteria. Title and abstract screening was completed, resulting in the removal of 5095 studies which clearly did not meet the inclusion criteria, 315 studies were eligible for full-text review. Most articles were excluded as they discussed non-sports-related concussions (n = 89), were secondary data analysis, narrative reviews, and expert opinions (n = 59), or contained participants over the age of 19 (n = 32). The remaining excluded articles resulted from no full text available (n = 56), no medical outcome data provided (n = 12), no management approaches discussed (n = 4), an epidemiological study (n = 5), and more serious brain injury being discussed (n = 5). Thirty-six studies were retained from the initial search. A further 42 articles were identified through citation screening, 41 of which were excluded. The final included studies numbered 36. Full details are displayed in the PRISMA flowchart (Figure 1).

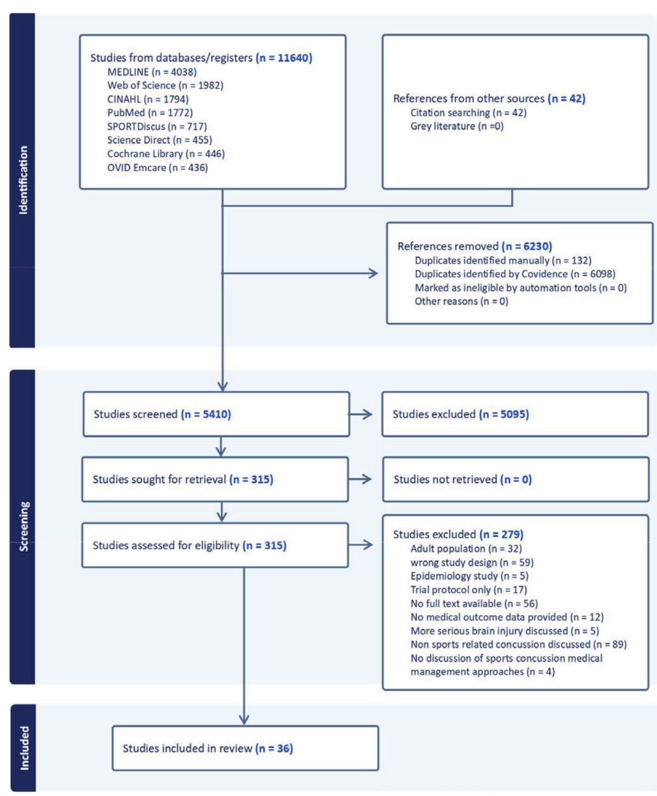

FIGURE 1 - PRISMA flow diagram.

Study characteristics

The majority of articles were from America (n = 25) (29-53) and Canada (n = 8) (54-61). The remaining studies were carried out in Switzerland (n = 1) (62), New Zealand (n = 1) (63), and Ireland (n = 1) (64). Various study design were reported: Prospective cohort studies (n = 9) (Level 4 evidence) (30-33, 54-57,64), case reports/series (n = 11) (Level 7 evidence) (41-48,60,52-53,63), randomised controlled trials (RTCs) (n = 12) (Level 2 evidence) (35-40,49,50,52,58-60), case-control studies (n = 2) (Level 4 evidence) (29, 51), quasi-experimental studies (n = 1) (Level 3 evidence) (61) and a feasibility trial design (n = 1) (Level 4 evidence) (34). Our categorisation of evidence level was informed by Melnyk and Fineout-Overholt (2023) (28). Across all studies, participants' ages ranged from ten to nineteen years old. Most studies reported on both male and female youth participants (64%, n = 23) (29,31-40,44,48-57,61), with 25% of studies reporting on male participants only (n = 9) (30,42-43,46-47,59-60,64) and the remaining 11% (n = 4) reporting on sole female participants in individual case reports (41,45,53,62). No trials reported on medical management outcome data for female-only participants. The results from this scoping review also highlight the saturation of data published from North America (69%, n = 25 from the USA and 22%, n = 8 from Canada). Only two studies were published in Europe (6%) and one from New Zealand (3%). Interestingly, there were no studies found from the United Kingdom (UK) that met the inclusion criteria for this scoping review.

Study themes

Four key themes were identified: (1) Exercise, activity, and neuromuscular training interventions (n = 14), (2) Pitch-side and sub-acute management, and monitoring (n = 6), (3) Novel treatment interventions (n = 5), and (4) Individual management in specific populations (n = 11). Individual study population details, study aims, methods, interventions, and results can be found in Table 1.

Theme 1 – Exercise, activity, and neuromuscular training interventions

1.1 Exercise/activity interventions efficacy

Eight studies reviewed the impact of exercise-based interventions or early activity levels for concussed youth athletes (29,33,37,40,49,54,56,59). Five of these specifically evaluated the utilisation of exercise interventions on recovery and post-concussion symptom scale (PCSS) Scores (37,40,49,56,59). Sub-threshold exercise programs (STEP) were found to support a reduction in PCSS scores and improved recovery times (40,49,56,59). Leddy et al. reported that symptom scores appeared to reduce in the exercise group; however, the reduction in scores was not statistically significant (37). Relative rest and placebo-like stretching interventions were less effective than STEP in relation to days to recovery and symptom reduction (37,40).

The remaining three studies in this theme evaluated physical activity levels post-concussion injury and reported outcome data (29,33,54). Early light-moderate exercise engagement after concussion was beneficial, and those not engaging in light exercise prolonged their return to play (33,54). Vigorous levels of physical activity post-injury delay recovery time (54). Completing exercise bouts lasting more than 15 minutes reduced the risk of developing PCS (29).

1.2 Early aerobic exercise testing safety and effects

Four studies examined the safety and efficacy of early exercise interventions post-concussion for the youth athlete (35,39,58,61). Two studies evaluated the Buffalo Concussion Treadmill test (BCTT), a provocative exercise testing protocol. Completing such a test within 1-10 days post-injury did not delay participant recovery (39). Participants with symptomatic SRC (SSRC) had a lower peak rate of perceived exertion (RPE), Oxygen consumption, Carbon dioxide production, and minute ventilation compared with control participants when completing the test (61).

Active rehabilitation and sub-maximal exercise interventions were safe, well tolerated, and reportedly provided therapeutic benefit for recently concussed participants (35,60). Chan et al. reported six adverse events during their study, yet concluded that these were unrelated to the intervention. Symptom exacerbation was experienced during initial sessions (resolving within 24 hours); however, they were able to tolerate 15 minutes of aerobic exercise by the final session, symptom-free (60). Worts et al. reported that early exercise interventions working at 40-60% of heart rate max yielded clinical improvements for those with a recent SRC (35). These studies support the safety of the use of such testing protocols and early exercise interventions for concussion management.

1.3 Neuromuscular training intervention

The two remaining studies under this theme explored outcomes following specialist rehabilitative interventions (34,38). One study was a feasibility trial for neuromuscular training (NMT) following a concussion injury and reported that it was possible to complete with their target population, and no adverse events occurred (34). A follow-up study by the same lead author established that an 8-week NMT programme after concussion may provide benefit to participants and reduce sports-related injuries and time lost from play over the following year from concussion (38).

Theme 2 – Pitch-side management approaches, sub-acute assessment, and monitoring

2.1 Removal vs no removal from play following concussion

Three studies evaluated recovery time and outcomes following removal from play versus no removal from play, post-concussion injury (31-32,57). Olsen et al. reported that youths who presented with early symptom onset (Initially symptom onset less than or equal to 15 mins from time of injury) were found to be more likely to be removed from play, compared to those with delayed symptom onset (Initial symptom onset more than 15 mins from time of injury). Those with delayed symptom onset took longer to return to play (RTP) following injury (57). Elbin et al. reported that delayed removal from play following concussion contributed to worse neurocognitive performance (ImPACT scores) and more severe symptom presentations. Recovery time was also found to be enhanced by immediate removal from play following injury (32). Zydna et al. found that athletes with increased initial symptom burden and later presentation to clinical assessment had prolonged recovery; however, there were no differences in overall recovery time between those who continued to play post-concussion versus those who didn't (31).

2.2 Assessment and monitoring

Three studies reported on the assessment and monitoring of the concussed youth athlete (30,55,64). The Cogstate brief battery (CBB) and King-Devick (K-D) test were unable to consistently provide accurate results for concussion assessment and monitoring (64). Emery et al. evaluated factors associated with clinical recovery in youth ice hockey players. And found that delayed presentation for clinical assessment (>7 days) was associated with delayed RTP clearance. Poorer SCAT3/5 tandem gait scores were associated with delayed clinical recovery in the players, alongside higher symptom evaluation scores and greater headache severity (55). Kelleher et al. reviewed outcomes of youth athletes presenting to a mTBI clinic, with RTP success achieved within 16.9 days 9 (mean) (Range 5-39). However, added limited data to guide concussion symptom management (30).

Theme 3 – Novel treatment interventions

Five studies reported on novel treatment interventions for concussed youth athletes (36,44,50-52). Of those, two studies aimed to establish the safety and efficacy of head and neck cooling therapy following injury (37,50), and a further study reviewed participant response to face cooling therapy (51). For head and neck cooling, the authors reported a greater and faster reduction in symptoms reported (from SCAT5 symptom evaluation) when compared to a control group using between-group mean differences at each visit and time point (36,50). Congeni et al. reported that the mean differences between groups (95% CI) at similar post-treatment time points yielded significantly greater and earlier reduction in symptoms for the treatment group during the baseline scores post-treatment, the following 72-hour visit pre- and post-treatment only. At the 10-day and 28-day visits, there was a reduced between-group mean difference of symptom scores up until the study endpoint, with a similar total recovery trajectory. Smith et al. reported no difference in total symptom scores pre-intervention between groups. The reduction in symptoms scores for the intervention group were reported as follows: a 14.4% reduction (95% CI, 6.4-22.4) at the initial visit, post-treatment; a 25.5% (95% CI, 15.3-35.1) greater reduction at 72 hour post initial treatment (following further treatment); and a 3.4% (95% CI, 28.1-14.9) greater reduction at the 10-day visit when compared with the control group (50). Similarly to Congeni et al., this study demonstrated head cooling efficacy for reducing symptom burden earlier; however, the control group's total recovery trajectory was also similar. Haider et al. reported no between-group differences in parasympathetic parameter responses for those who were concussed and those who weren't. Interestingly, they found that in athletes with a prior history of concussion, heart rate and heart rate variability responses were significantly different from the control group, suggesting reduced adaptability of the autonomic nervous system (51).

A further novel treatment option studied was the use of docosa-hexaenoic acid (DHA) supplementation and its effects on recovery from SRC. This study found that no adverse effects were associated with DHA supplementation, and there was no improvement in recovery times for those taking DHA (52).

The remaining study charted hyperbaric oxygen therapy for the treatment of mTBI. No adverse effects were charted, and with limited data presented, the authors reported that HB02 may be an effective treatment following concussion, but their results were inconclusive. The efficacy of the intervention was not evaluated, and the purpose was to describe the effect and report any adverse events, of which there were none (44).

Theme 4 – Individual accounts of concussion management in specific populations

Eleven of the included studies were case reports/series. These reports were heterogeneous in terms of the participant characteristics and interventions reported. These case series/reports provide individual accounts of concussion management in specific populations and remain poorly generalisable. These reports can be groups into sub-themes as outlined below.

4.1 Concussion and mental health

Three case reports/series charted interventions and outcomes of youth athletes requiring more specialist input and transitions of care to mental health services/ teams following concussion and with such complaints: persistent mood disorder and anxiety (n = 1 participant) (45); post-concussion symptoms in combination with pre-existing mood disorders (n = 2) (47); prolonged PCS and post-traumatic stress symptoms (n = 1) (62). All cases report on the need for enhanced multidisciplinary team communication and management (45,47,62). One study reports the need for improved mental health screening in all athletes to identify risk factors for PCS (47). Only one case reported positive outcomes (45), whilst the remaining two cases reported poor, lasting mental health complaints in the young athletes who required ongoing psychological support (47,62).

4.2 Specialist medical case reports/series

A further four studies report on specialist medical interventions or the case of concussion cases with medical complications or delayed recovery (42,46,48,53). Lunardini et al. (2009) reported on treating a concussed individual with diabetes and reported the potential for abnormal blood sugars to have contributed to delayed recovery. The individual in this case had a history of poor blood sugar control and had a protracted recovery of 6 months and required specialist medical input and academic protections (42).

Stiller-Ostrowski reported one case of a young athlete with a cranial nerve palsy following a concussive injury. The patient in this case remained symptomatic at five months post-injury, with visual disturbance. He was provided with advice and risk education from a specialist neuro-ophthalmologist; however, he returned to full contact sport at month six, reporting a full improvement in symptoms, subjectively (46). Bramley et al. evaluated the use of steroids for severe post-traumatic headaches, following a concussion incident, and reported improvements for both participants with physician monitoring and medication management (48). McNally et al. reported on the requirement for more advanced multidisciplinary and neuropsychology treatment input for an injured female youth horse rider, who had failed to respond to usual concussion care. She recovered by day 75, post injury, with an ongoing mild functional gait disturbance and remained on medication for her underlying psychiatric conditions (53).

4.3 Chiropractic management

Two case reports/series evaluated outcomes following chiropractic interventions (43,63). Olson et al. charted the recovery of three youth football players with concussion and reported improvements in cervical spine range of movement, muscular spasms, and neck pain alongside associated 'concussive/vestibular symptoms' following manual therapy interventions (43). The authors positively frame their interventions to have enhanced return to play outcomes. Hunt et al. charted the recovery of a youth skateboarder presenting for manual therapy interventions post-concussion (63). The authors report the potential for their intervention to have improved symptoms but draw no conclusion due to their expression of a weak evidence base for improvement claims.

4.4 Normative return to play rehabilitation

A further two studies in this review chart rehabilitative approaches for athletes with concussions (41,60). Gunter et al. reported on the physical therapy management of a female equestrian athlete with a history of multiple concussions and charts a return to sport at 8 weeks with no concerning complications (41). Marsh et al. reported on a standardised return to play protocol for a young hockey player, who was able to return to sport after three weeks with no ongoing symptoms (60). Both cases provide a narrative account of practitioner intervention and report on outcomes.

TABLE 1 - Data extraction – Participant and study details

Authors	Participant details				Study Design
	N total **N. control (CG) & intervention groups (IG)**	**N, male (M) & Female (F)**	**Age range (years)**	**Mean Age (years) ± standard deviation (SD)**	
Theme 1 – Exercise, activity, and neuromuscular training interventions					
1.1 Exercise/activity interventions efficacy					
Chrisman et al., 2019	30 IG = 19 CG = 11	M = 12 F = 18	12–18	15.5 ± 1.6	Pilot RCT
Gagnon et al., 2016	10	M = 7 F = 3	14–18	N/A	Pilot prospective cohort study
Micay et al., 2018	15 IG CG	M = 15 8 7	14–18	 15.8 ± 1.2 15.6 ± 1.0	RCT
Leddy et al., 2019	103 AE = 52 Stretching group (SG) = 51	M = 55 F = 48 M = 28 F = 24 M = 27 F = 24	13–18	 15.3 ± 1.6 15.4 ± 1.7	Multicenter prospective RCT
Leddy et al., 2021	118 AE group = 61 SG = 57	M = 74 F = 44 M = 38 F = 23 M = 36 F = 21	13–18	 15.5 ± 1.4 15.9 ± 1.4	Multicentre prospective RCT
Seehusen et al., 2021	32 RTP ≥ 28 Days Post-Injury = 17 RTP < 28 Days Post-Injury = 15	M =18 F = 14 M = 9 F = 8 M =9 F = 6	12–18	 14.9 ± 1.9 15.4 ± 1.5	Observational prospective cohort study
Lishchynsky et al., 2019	30 Low activity group (LAG) = 15 High activity group (HAG) = 15	M = 25 F = 5 M = 11 F = 4 M = 14 F = 1	12–17	N/A	Prospective cohort study
Neely et al., 2023	49 PPCS group No PPCS group	M = 24 F = 25 M = 11 F = 12 M = 13 F = 13	12–18	 14.7 ± 1.9 14.9 ± 1.7	Prospective observational case-control study

(*Continued*)

TABLE 1 - (*Continued*)

Authors	Participant details				Study Design
	N total **N. control (CG) & intervention groups (IG)**	**N, male (M) & Female (F)**	**Age range (years)**	**Mean Age (years) ± standard deviation (SD)**	
1.2 Early aerobic exercise testing safety and effects					
Morissette et al., 2020	74		14–19		Quasi-experimental nonrandomized study
	Symptomatic SRC (SSRC) = 34	M = 19 F = 15		16.4 ± 1.2	
	CG = 40	M = 13 F = 27		15.9 ± 0.8	
Chan et al.,2018	19	M = 5 F = 14	12–18	15.5 ± 1.7	Single-site RTC comparing TAU to TAU plus AR with blinded assessors
	Treatment at usual (TAU) = 9	M = 1 F = 8		15.1 ± 1.42	
	Active rehabilitation (AR) group = 10	M = 4 F = 6		15.9 ± 1.66	
Leddy et al., 2018	54	M= 37 F = 17	14–19		Prospective RTC
	BCTT = 27	M = 18 F = 9		15.19 ± 1.45	
	CG = 27	M = 19 F = 8		15.63 ± 1.36	
Worts et al., 2021	30	M = 20 F = 10	13–18		RCT
	SRC group = 19	M = 13 F = 6		15.8 ± 1.4	
	Healthy group = 11	M = 7 F = 4		16.3 ± 0.9	
1.3 Neuromuscular training intervention					
Howell et al., 2021	27	M = 17 F = 10	12–18		Feasibility trial.
	NMT = 11	M = 7 F = 4		14.7 ± 1.7	
	CG = 14	M = 9 F = 6		14.8 ± 1.5	
Howell et al., 2022	27	M = 16 F = 11	12–18		block-stratified RCT
	NMT group = 11	M = 7 F = 4		14.7 ± 1.7	
	CG = 16	M = 9 F = 7		15.3 ± 1.8	
Theme 2 – Pitch-side management approaches, sub-acute assessment, and monitoring					
2.1 Removal VS no removal from play following concussion					
Olson et al., 2020	144	M = 88 F = 56	N/A	14.6 ± 1.8	Prospective cohort study - qualitative data collection
	Delayed symptom onset group = 24	M = 15 F = 9		14.2 ± 2.0	
	Early symptom onset group = 120	M = 73F = 47		14.68 ± 1.7	
Elbin et al., 2016	69	M = 51 F = 18	12–19		prospective, repeated measures design
	RFP = 35	M = 27 F = 8		15.61 ± 1.65	
	Continued to play (CTP) = 34	M = 24 F = 10		15.35 ± 1.73	
Zynda et al., 2022	441	M = 217 F = 224	13–18		A prospective cohort study
	PLAY = 231	M = 109 F = 122		14.9 ± 1.29	
	NO PLAY = 210	M = 108 F = 102		14.8 ± 1.33	
2.2 Assessment and monitoring					
Cosgrave et al., 2023	135	M = 135	15–19	16.7 ± 0.8	Prospective cohort study.
	Prior history of concussion = 61	M = 61		16.7 ± 0.8	
	No prior history of concussion = 74	M = 74		16.6 ± 0.9	
Emery et al., 2021	329	M = 279 F = 50	11–17	N/A	prospective sub-cohort study
Kelleher et al., 2014	28	M = 28	13–18	15.3*	Pilot study plus cross-sectional survey
	Survey respondents = 266	M/F = Not reported		15.5*	

Authors	Participant details				Study Design
	N total **N. control (CG) & intervention groups (IG)**	**N, male (M) & Female (F)**	**Age range (years)**	**Mean Age (years) ± standard deviation (SD)**	
Theme 3 – Novel treatment interventions					
Congeni et al., 2022	45 Treatment group = 28 CG = 27	M = 28 F = 27 M = 14 F = 14 M =14 F = 13	12–17	 14.7 ± 1.6 14.25 ± 1.4	A randomized, nonblinded pilot trial.
Smith et al., 2024	167 CG = 88 Treatment group = 79	M= 82 F = 85 M = 37 F =51 M = 45 F = 34	12–19	 15.1 ± 1.6 15.2 ± 1.6	A multi-site, prospective, longitudinal RCT
Roby et al., 2021	8	M = 5 F = 3		16.0 ± 1.2	Case series
Miller et al., 2022	40 CG = 20 Treatment group = 20	M = 27 F = 13 M = 13 F = 7 M = 14 F = 6	14–18	 15.97 ± 1.03 16.02 ± 1.19	Double-blind, parallel-group, pilot RCT
Haider et al., 2025	47 CG = 24 Concussed group = 23	M = 26 F = 21 M = 14 F = 10 M = 12 F = 11	13–18	 15.83 ± 1.55 15.48 ± 1.16	Prospective case-control study
Theme 4 – Individual accounts of concussion management in specific populations					
4.1 Chiropractic management					
Olson et al., 2018	3	M = 3	11–16	N/A	Case series
Hunt et al., 2018	1	M = 1	13	N/A	Case report
4.2 Concussion and mental health					
Sherry et al., 2021	1	F = 1	18	N/A	Case report
Tucker et al., 2019	2	M = 2	16–17	N/A	Case series
Waldmeier-Wilhelm et al., 2019	1	F = 1	14	N/A	Case report
4.3 Specialist medical case reports/series					
Lunardini et al., 2009	1	M = 1	16	N/A	Case report
Stiller-Ostrowski 2010	1	M = 1	19	N/A	Case report
Bramley et al., 2012	2	M = 1 F = 1	10–15	N/A	Case series
McNally et al., 2024	1	F = 1	16	N/A	Case report
4.4 Normative return-to-play rehabilitation					
Gunter et al., 2018	1	F = 1	14	N/A	Case report
Marsh, Fraser, and Marsh. 2013	1	M = 1	14	N/A	Case report

*Reported as average age. Did not specify mean/ median

TABLE 2 - Data extraction - Aims, methods, outcome measures and results

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Theme 1 – Exercise, activity, and neuromuscular training interventions				
Exercise/activity interventions efficacy				
Chrisman et al., 2019	Evaluate feasibility/ acceptability for STEP with minimal in-person visits for persistent SRC, and efficacy for improving symptoms, health-related quality of life, and fear-avoidance.	• Randomised to CG (home stretching program(HSP)) or IG (6-week STEP). • In-person assessments at study entry and at 6 weeks (post-intervention). • Online weekly assessments of concussion symptoms during intervention, and surveys (PedsQL, FOPQ-P/C) at baseline, 6 weeks, 3 and 6 months. • Accelerometry was completed for 5– 7 days at baseline and at 6 weeks	• Feasibility and acceptance. • Health behaviour inventory. • PedsQL© • Physical activity (Accelerometry) • Fear of Pain Questionnaire – Parental/Child (FOPQ-P/FOPQ-C).	• Symptoms during exercise reported by 2/11 participants in CG and 7/19 in IG, No dropouts to symptom exacerbation. • Intervention significantly reduced symptoms (controlling: age, sex, and prior concussion). • The rate of symptom improvement is slower among youth with chronic symptoms (9–22 weeks & >22 weeks) compared to acute symptoms (<9 weeks). • PedsQL© improved in IG compared to CG. • FOPQ-P reduced overall, but not improved for IG. No differences were found between FOPQ-C scores between groups.
Gagnon et al., 2016	Examine the effectiveness of AR intervention for adolescents slow-to-recover after SRC.	• Participants (SCR slow recovery with persistent symptoms ≥ 4 weeks post injury). • The AR program lasted 6 weeks with testing throughout (10-day intervals).	• Post-concussion symptoms (PCS) using the post-concussion scale (PCSS).	• Mean time of assessment post injury: 7.9 weeks (range: 3.6–26.2 weeks). Significant decrease of PCS at 6 weeks.
Micay et al., 2018	Feasibility of post-acute structured AE intervention in concussed and symptomatic adolescent athletes.	• Randomized (IG or CG). • CG -6-stage activity progression, assessed at 1,2,3,4 weeks. • RTP decisions by a blinded sports medicine physician. • IG completed standardised AE intervention on day 6 post-injury, plus a six-stage activity progression protocol. • AE - 8 sessions utilising a step-wise approach (duration/ intensity).	• Symptom status pre-post exercise sessions/ completion of intervention. • Clinical recovery: symptom status at weeks 1, 2, 3, and 4. • Medical RTP clearance date.	• AEs are not associated with symptom exacerbation. • PCSS were lower than pre-season scores post-exercise, but not statistically significant. • No statistically significant difference in mean time to medical RTP between groups (36.1 ± 18.5) in the EG and (29.6 ± 15.8) in the UCG. • Significant association between time to medical clearance and acute PCSS at day 5 postinjury (p=0.04). • IG-Significant decrease in symptoms between weeks 1 and 3. (Same result not achieved in UCG until week 4).
Leddy et al., 2019	Effectiveness of sub-symptom threshold AE vs stretching programme during acute recovery following SRC.	• Randomised to AE or SG < 10 days of sustaining SRC. • Treating physicians were blinded to the allocated groups. • AE-daily use of bike at target HR. • SG completed the progressive stretching program. (20 mins per day - HR monitor)	• Days to recovery. • Return to normal exercise tolerance on a treadmill. (Normal recovery <30 days, delayed >30 days).	• AE participants recovered in 13 days (median). • The SG took 17 days (Median) to recover. • There was a non-significant incidence of lower delayed recovery in the AE group, compared to the control group.

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Leddy et al., 2021	Evaluate safety, efficacy, and adherence with prescribed early targeted heart rate sub-symptom threshold AE, compared to stretching exercise for SRC recovery.	• Completed PCSI and BCTT at initial visit and during up to 3 subsequent weekly visits, unless recovered sooner. • Randomly assigned to AE or placebo SG < 10 days of SRC. • AE - exercise at home at up to 90% of max HR-20 min a day. • SG - light stretches and breathing exercises that would not elevate HR.	• Clinical recovery within the 4-week intervention period. • Development of PCS beyond 28 days post-injury.	• The AE group was more likely to recover within 4 weeks after injury compared to the SG. • During the entire 4-month follow-up period, the median days to recovery for the AE group was 14 days (IQR 10–25) versus 19 days (13–31) for the SG. • There was also a reported 48% reduced risk of developing PCS in AE. • There were no adverse events reported for the study duration.
Seehusen et al., 2021	To examine the association between objective physical activity metrics and clinical recovery after concussion.	• Recruited following a concussion diagnosis and presenting within 14 days with a PCSI score ≥ 9. • Evaluated at two time points + reported PCSI scores: Initial visit and at RTP clearance visit. • Between visits, participants wore an activity tracking device (calculated average: steps per day, sessions per week; time spent during each specific exercise session; and maximum HR during each session.	• RTP clearance • PCSI • Activity data (steps per day/ exercise frequency/ exercise duration/ exercise intensity.	• 17 participants (53%) required ≥28 days to RTP. • Those ≥28 days RTP reported significantly greater symptom severity at initial assessment than those who RTP within 28 days of injury. • First 2 weeks, the RTP clearance ≥ 28 group took significantly fewer steps per day, exercised fewer days per week, significantly lower average total exercise volume per week compared with the <28 day RTP group. • The highest classification accuracy between groups was ≥10,250 average steps/day and completing ≥4 exercise sessions per week, and ≥135 total minutes per week.
Lishchynsky et al., 2019	To evaluate the association between the amount of MVPA during the first 3 days following concussion diagnosis and time to medical clearance (days) to RTP in youth ice hockey players.	• Completed SCAT3, vestibulo-ocular/ cervical spine function tests. • Physicians were blinded to activity and baseline symptom reports. • Participants are advised to rest until the acute symptoms resolution. • Exposure: amount of time (minutes) spent in MVPA in the initial 3 days (72 h) immediately following concussion diagnosis. MVPA was measured with raw accelerometer data categorised into (sedentary, light, moderate, vigorous) • 3 days exposure window to ensure accurate initial physical activity.	• SCAT3 (PCSS scores) • RTP clearance timescale. • Symptom duration. • Number of days to initiation of activity (injury date to initiation of activity) • Date of return to school (self-reported).	• Participants in both groups presented to the clinic a median of 4 days post-injury (low activity: IQR 3-5 days and high activity: IQR 3-7 days). • The median total number of symptoms reported at initial appointment was 13 out of 22 (IQR 9-20) for the LAG and 10 (IQR 6-14) for the HAG. • Median symptom severity score LAG = 31 (IQR 14-51) and LAG = 14 (IQR 8-29). • Median amount of time LAG spent in MVPA = 110.7 min (IQR: 76.2–131.0 min). HAG = median of 217.2 min in MVPA (IQR: 184.2-265.2 min). • Four participants (13.3%) did not miss any school days and RTP the day after injury. • HAG took more time for RTP clearance ($p = 0.041$). No significant differences in secondary measures.

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TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Neely et al., 2023	Determine whether sleep behaviour (duration/ timing) and/or physical activity (steps/ day, exercise frequency, duration, intensity) during the first month post-concussion are associated with PCS development.	• completed an initial medical/ injury history questionnaire. • Participants remotely tracked physical activity, sleep, and exercise over 2 weeks following their initial assessment.	• PCSI. • Main outcome variable - persisting post-concussion symptoms (PPCS): A symptom resolution of >28 days or <28 days (defined as no PPCS).	• 47% developed PCSS. A higher proportion reporting PCSS had an ADHD diagnosis. • The PPCS group took significantly fewer steps per day and exercised fewer days per week. They also spent more time in bed awake. Exercise duration/ intensity and sleep times were not significantly different between groups. • Odds of PPCS significantly increased with fewer exercise sessions per week. • Completing more exercise sessions lasting >15 minutes during the recovery period reduced the risk of PPCS.
1.2 Early aerobic exercise testing safety and effects				
Morissette et al., 2020	To compare cardiorespiratory (CR) response to a graded AE challenge between adolescents with symptomatic sport-related concussion (SSRC) and healthy control subjects.	• Graded AE challenge using BCTT. • Heart rate (HR), Rate of perceived exertion (RPE), and symptom status data were collected every minute during treadmill testing, whereas cardiorespiratory data were recorded every minute using 20-s averages. • The BCTT is either the participant reached volitional fatigue or the participant experienced a symptom-limited threshold (An increase in self-reported symptom status by two or more points using a 10-point standardized Likert scale). • Peak HR, blood pressure (BP), and cardiorespiratory data were recorded, and a post-exercise PCSS was completed.	• HR • consumption (VO_2) • Carbon dioxide production (VCO_2) • Minute ventilation (VE) • Taken at rest/ test termination. • Change from rest in variables (ΔHR, ΔVO_2, ΔVCO_2, and ΔVE) during the first five stages of the BCTT.	• Symptoms/symptom severity were higher in the SSRC group compared with CG ($p < 0.0005$). • SSRC group achieved a lower peak stage during BCTT compared to CG ($p < 0.0005$), lower peak RPE ($P = 0.023$), lower relative peak VO_2, VCO_2, and VE compared with CG ($p < 0.0005$). • SSRC - lower peak SBP($p < 0.0005$), higher peak diastolic BP (DBP) ($p < 0.0005$). • Peak HR + %HRmax is lower among male SSRC patients compared to male controls ($p < 0.0005$). Female SSRC - higher peak HR + %HRmax ($p = 0.016$) ($p = 0.018$). • The highest BCTT stage was reached lower level among females vs males ($p = 0.04$), peak relative VO_2, VCO_2, and VE all lower in female control vs male controls ($p < 0.0005$). • No group-based differences ΔHR, ΔVO_2, ΔVCO_2 ΔVE. • RPE is higher among SSRC patients compared with CG.
Chan et al., 2018	To examine the safety and tolerability of an AR program for adolescents who are slow to recover from an SRC. Secondary aim: To estimate the treatment effect for this intervention.	• Participants were randomized to either TAU or TAU plus an AR program. • TAU consisted of symptom management and RTP advice, return-to-school facilitation, and physiatry consultation. • The AR program involved in-clinic sub-symptom threshold aerobic training, coordination exercises, and visualisation and imagery techniques with a physiotherapist (mean, 3.4 sessions) as well as a HEP, over 6 weeks.	• Adverse events. • In-clinic symptom exacerbation during AE. • PCSS	• 6 adverse events in each group. The most common was PCSS change (>10 points) from one week to the next. Adverse events were reportedly unrelated to the intervention. • AR group, there were worsening symptoms (>1 on a 0-10 scale) in 37% (11/30) of clinic sessions involving AE. Most symptom exacerbations occurred in the 1st or 2nd AE session. All symptom exacerbations resolved within 24 hours, in most (10 of 11 instances) within 15 minutes of discontinuing exercise. • All participants were able to tolerate 15 minutes AE without symptom exacerbation by their last clinic session.

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Leddy et al., 2018	Evaluate the systematic assessment of exercise tolerance in adolescents shortly after SRC and determine the prognostic utility of this assessment.	• Participants were randomized to BCTT within 10 days of sustaining a concussion or standardised care (no test). • Intervention: BCTT on the day of presentation to the clinic (visit 1), Secondary follow-up visit, approx. 14 days after, or approximately. 21 days post-injury.	• Days to recovery and typical (≤21 days) versus prolonged recovery (>21 days).	• Days to recovery + typical vs. prolonged recovery were not significantly different between groups. Symptom scores decreased over 14 days in both groups, and symptom scores did not increase the day after visit 1 (Intervention group), BCTT. • A lower HR threshold on visit 1 was strongly associated with prolonged recovery time and prognosis. BCTT used within one week post SRC did not delay recovery.
Worts et al., 2021	Examine acute effects (pre, during, post-intervention) of two different AE intensities/ rest on autonomic, oculomotor, vestibular function, and symptom burden in patients with SRC and compare their responses to sex-matched, age-stratified, non-concussed (HEALTHY) student-athletes.	• Two study groups were observed: (1) student athletes treated for an SRC within 3-7 days post-injury. (2) non-concussed (HEALTHY) athletes. • All participants were randomised to a single session of one of three 20-minute interventions using a double-block design (Sex: Male/Female; Age: 13–15 and 16–18) • (1) 40% of Age-Predicted HRMAX (40HR). • (2) 60% of Age-Predicted HRMAX (60HR). • (3) seated, non-exercise (NOEX). • Participants were fitted with test equipment (Blood pressure cuff and HR monitor)	• HR variability (HRV) using an electrocardiogram (ECG) strap. • Blood pressure. • Mean arterial pressure (MAP) was derived from SBP and DBP. • RPE using Borg's Category Ratio-15 scale. • King-Devick (K-D) test. • Vestibular Oculomotor Screening (VOMS). • PCSS.	• SRC group reported greater provocation during VOMS (more symptoms & more severe symptoms than HEALTHY participants). • Near point convergence (NPC) distance and K-D times did not exhibit an injury status group effect. 15/16 SRC group completed AE session, 13/15 who completed AE displayed improvements beyond reliable change on at least one of the clinical test measures. None displayed a group effect during the orthostatic stressor. • In the SRC and HEALTHY groups that exercised, participants generally exhibited improvements in clinical measures, even while exerting at 40–60% of HRMAX. • Pre-exercise HRV and MAP were significantly different (p's<0.001) during treatment but returned to pre-exercise values within 5 min of recovery in both groups. Both groups exhibited similar reductions pre- to post-intervention for symptom severity and count ($p < 0.05$), three VOMS items ($p < 0.05$) not K-D time.
1.3 Neuromuscular training intervention				
Howell et al., 2021	To determine the feasibility of an 8-week neuromuscular training (NMT) program initiated upon RTP clearance following concussion.	• 3 assessments: 14 days post-concussion, after RTP, and 8 weeks after Visit 2. • Visit 1: Independent physician assessment. No study interventions between Visits 1 and 2. • Following RTP clearance, participants attended visit 2: Randomized to NMT or CG. Attended a final assessment 8 weeks after Visit 2. • NMT: 2x per week with athletic trainer.	• PCSI • Patient Reported Outcomes Measurement Information System • Tampa Scale of Kinesiophobia. • Reaction time, single/dual task gait, and balance outcomes.	• No adverse events in either participant group during the intervention period. • The median time to symptom resolution was 17 days [interquartile range (IQR) = 12, 43] for the intervention group and 19 days [IQR = 11, 49] for the standard-of-care group. • The median time to medical clearance to RTP for the intervention group was 22 [IQR = 15, 49] days, and 35 [IQR = 15, 62] days for the standard-of-care group. • 55% of the NMT group were able to complete all 16 sessions.

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TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Howell et al., 2022	To examine the efficacy of an NMT intervention on acute sports-related time-loss injury (SRTLI) over the subsequent year relative to standard of care.	• Twenty-seven youth athletes assessed initially post-concussion and after RTP clearance, randomly assigned to NMT intervention or standard of care group. • The intervention included guided strength exercises with a landing stabilisation focus. Standard of care received no recommendations. • For the subsequent year, a completed log of sports-related injuries.	• Time from post-concussion RTP clearance until injury. • Incidence of musculoskeletal injuries, plus the total number of injuries sustained over the monitoring year, and injury severity.	• First year after RTP clearance, SRTLI is more common among CG relative to NMT intervention (75% [95% CI, 48%-93%] vs 36% [95% CI, 11-69%]). • Adjusting for age and sex, the hazard of subsequent injury in the CG group was 3.56 times (95% CI, 1.11-11.49; p = .0334) that of the NMT group. • Age and sex-adjusted injury incidence was 10.2 per 1000 competitive exposures (95% CI, 3.7-28.4) in the CG & 3.4 per 1000 (95% CI, 0.9-13.4) in the NMT group. • Adjusting for age & sex, Injury incidence was higher for the CG vs NMT intervention.
Theme 2 – Novel treatment interventions				
Congeni et al., 2022	To determine the safety and efficacy of head and neck cooling when applied up to 8 days after concussion among adolescent athletes.	• Within 8 days of SRC: Randomized CG/ treatment group. • The treatment group received both standard treatment and head and neck cooling therapy using the Pro-2cool device. • SCAT5 symptom scores charted post-injury assessment visit, before and after treatment/ standard treatment (0-8 days); 72 hours, before/ after treatment or standard treatment (±24 hours from initial visit); 10 days (±3 of initial visit), 4 weeks (28 days ± 7 days)	• SCAT5 symptom severity score assessment	• Significant main effects (group and time, p < 0.01 for each), as well as interaction between time and group (p = 0.017) for absolute differences in SCAT5 total symptom severity scores from injury to follow-up. • Between groups mean differences (95% CI) at each time points demonstrated significantly greater and earlier reduction in symptoms for the treatment group: initial visit posttreatment 14.1 (6.7-21.4), 72 hours visit pre-treatment 9.2 (-3.3- 15.1), 72 hours visit post-treatment 15.5 (8.2-22.8), 10 days visit 5.8 (1.9-13.5), and 4 weeks visit 0.7 (-9.5-10.9). • No significant adverse events were reported..
Smith et al., 2024	To determine whether an investigational head–neck cooling device, Pro2cool, can better reduce symptom severity compared with standard post-concussion care in early adolescent athletes after a SRC.	• Randomised to CG or treatment group (standard care plus head–neck cooling therapy using Pro2cool device applied at two different post-injury time points). • SCAT5 completed (IVPreT) within 8 days of injury and immediately following this, received control/ treatment. • Participants returned 72 hours after the IVPreT for the 2nd round of treatment. SCAT5 tests completed pre-/post-intervention/control. SCAT5 scores were gathered at day 10 + 28.	• SCAT5 symptom severity scores. • Adverse reactions.	• The treatment group experienced a 14.4% greater reduction in SCAT5 symptom severity scores at the initial visit post-treatment, a 25.5% greater reduction at the 72-hour visit post-treatment, and a 3.4% greater reduction at the 10-day visit compared with CG. • Significant group absolute differences from baseline SCAT5 scores favouring the Pro2cool treatment arm at the initial visit post-test, at the 72-hour visit post-test, and at the 10-day visit. • 36 adverse events reported, 13 associated with the device (3 - moderate severity). No significant association between experimental group/event severity.

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Roby et al., 2021	Describe the effect of HBO_2 therapy on reducing initial symptom burden in acutely concussed high school student-athletes compared to two different placebo treatments.	• Eight participants randomised and blinded to: (1) Hyperbaric therapy with 100% oxygen (HBO_2), 100% O2 at pressure (n = 3) (2) Hyperbaric therapy with medical-grade air (HBA) (n = 3) (3) 100% O_2 normo-baric therapy (O_2 Therapy) (100% O_2 therapy with negligible pressure) (n = 2). • PCSS was completed before and after treatment.	• PCSS • SAC • Number of days from injury until the physician permitted the student-athlete to return to activity.	• No statistical analysis was reported between treatment arms. The below % reported represents a total symptom score reduction. • HBO_2 RTP average of 13.7 ± 5.1 days (median = 15 days). Participant 3 (90.2%), 6 (77.8%), and 7 (93.5%). • HBA Therapy RTP average of 13.0 ± 5.7 days (median = 13 days). Participants 2 (87.5%) and 5 (81.1%). • O_2 therapy RTP average of 19.0 ± 16.5 days (median = 11 days). Participants 1 (83.3%) and Participant 8 (95.7%). Participant 4 (93.1%) at visit 4.
Miller et al., 2022	Examine the use of Docosa-hexaenoic acid (DHA) for the treatment of SRC in an adolescent population. (To also determine if adverse reactions occurred with higher dosage of DHA and to examine athlete outcomes following DHA supplementation.)	• Participants were randomised to the control or intervention arm within 4 days of suspected SRC. • Participants were advised to take 4 DHA capsules daily (total 2000mg per day). • Participants were evaluated at weeks 1,2,4, and 12.	• SCAT3 • Adverse effects reported by a sports medicine physician. • Drug compliance. • Time to 'symptom-free' and time to initiation of RTP.	• The use of 2000 mg per day of DHA was well tolerated. • This supplementation did not significantly improve recovery times in adolescent athletes.
Haider et al., 2025	To evaluate the Face cooling (FC) response in adolescent athletes with SRC while they were symptomatic after clinical recovery.	• Participants attended the research lab within 10 days of injury (visit 1) and at 2 weeks following successful graded return to play. • FC treatment was applied following a standardised approach, and parasympathetic responses were recorded.	• HRV/Mean arterial BP • HR/MAP/Cardiac Output (CO)/ Stroke volume (SV) • Root mean square of the successive differences (RMSSD) of R-R interval (RRI) • Low frequency (LF) and High frequence (HF) ratio	• During FC, no significant differences were found between groups at the initial visit in rate of change in HR, mean arterial BP, RMSSD, or LF/HF ratio. • No differences amongst those with delayed recovery from concussion. • Previous history or concussion had a significant effect on HR and HRV responses to FC intervention.

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TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Theme 3 – Pitch-side management approaches, sub-acute assessment, and monitoring				
3.1 Removal VS no removal from play following concussion				
Olson et al., 2020	Examine: Delayed symptom onset in youth athletes sustaining SRC; Effect of symptom onset on initial symptom severity, length of recovery, and consequent development of delayed recovery; Impact of symptom onset on pitch-side management.	• Prospective recruitment of youth athletes sustaining SRC from the Pan AM concussion programme. • Sideline assessment data not recorded. • Reported standardised procedure for athletes at baseline/ and following injury (Pan AM concussion programme). All patients were assessed following an SRC by a single neurosurgeon. Follow-up included a weekly visit or dictated by the rate of recovery. Recovery was defined as the resolution of symptoms or a normal neuro exam. Patients completed the graded RTP (GRPT) protocol prior to full RTP.	• Delayed symptom onset (DSO) ≥ 15 mins from injury. • Early symptom onset (ESO) <15 mins since injury. • Length of clinical recovery (injury date - final follow-up). • Delayed recovery reported as >28 days to resolution.	• Median time to initial assessment was 5.0 days, and the median PCSS scores were 22. • DSO athletes were assessed at 6.5 days, whilst ESO athletes were assessed at 5.0 days. There were no significant differences between median symptom scores at initial medical assessment between ESO/DSO athletes. • DSO were cleared to play at 23 days (median), and those with ESO at 21 days (median) following injury. • SRC patients who experienced ESO were significantly more likely to be removed from play (RFP) compared to those with DSO.
Elbin et al., 2016	To compare recovery time and related outcomes between athletes who were immediately RFP and athletes who continued to play with an SRC.	• Compared neurocognitive performance, symptoms, and recovery time between 35 athletes immediately removed after an SRC (REMOVED group), compared to 34 athletes who continued to play (PLAYED group) with SRC. • Neurocognitive and symptom data were obtained at baseline and at 1 to 7 days and 8 to 30 days after an SRC.	• ImPACT scores • Recovery time (defined as the total number of days from the date of injury to the date of receiving RTP clearance).	• PLAYED took longer to recover than the REMOVED group (44.4 ± 36.0 vs 22.0 ± 18.7 days; $p = .003$) & were 8.80 times more likely to demonstrate protracted recovery (≥21 days) ($p < .001$). • Removal from play status was associated with the greatest risk of protracted recovery (adjusted odds ratio, 14.27; $p = .001$) compared with predictors (eg, sex). • PLAYED group exhibited significantly worse neurocognitive and greater symptoms vs REMOVED.
Zynda et al., 2022	Identify the frequency of continued play (CP) following SRC, defined as continuing athletic activity on the same day following a suspected SRC, characteristics associated with CP, and whether CP was associated with worse outcomes.	• Participants were divided into two groups: Those who continued to play following SRC (PLAY) and those who did not (NO PLAY). NO PLAY - Immediately removed from play. • Data were collected prospectively at the time of initial clinic visit and three months following enrolment. • Assessments at enrolment: concussion symptom log, mBESS, ImPACT. Psychological assessments included: Generalized Anxiety Disorder Scale (GAD-7), Patient Health Questionnaire (PHQ-8), Brief Resilience Scale (BRS).	• Concussion symptom log • ImPACT scores • mBESS scores • GAD-7 • PHQ-8 • BRS • Time to symptom resolution. • Time to RTP	• 52.4% were in the PLAY group and had less severe balance problems from the day of injury ($p = 0.016$), but reported trouble with falling asleep, concentrating, and memory at their initial visit ($p < 0.05$). • No significant group differences were found when comparing remaining symptoms from the day of injury, symptom log. Symptom scores – injury day not significantly different. • PLAY group: worse ImPACT scores ($p = 0.042$). • No significant difference between groups for time to symptom resolution, time to initiate RTP ($p = 0.381$), or RTP time ($p = 0.776$). • Greater symptom severity score at the initial visit and longer time to presentation were associated with prolonged recovery in both groups ($p < 0.01$).

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
3.2 Assessment and monitoring				
Cosgrave et al., 2023	To characterize the incidence, severity, and recovery of SRC in schoolboy rugby players and explore whether the SCAT, Cogstate Brief Battery (CBB), and the K-D test can be used to monitor concussion status through to full recovery.	• Participants attended for baseline testing during preseason and were followed up over the 2016-2017 playing season. • Participants diagnosed with SRC during the season attended for post-concussion testing on a weekly basis until fully recovered. At each post-concussion appointment, the full battery of investigations was repeated. • Participants were prescribed an individualised rehabilitation programme, which is considered the gold standard management of concussion and was not part of the study in itself. • Participants adhered to the Irish Rugby Football Union (IRFU) concussion guidelines (IRFU Guide to Concussion in Amateur Rugby Union) for their age group.	• Questionnaire (sleep, mood, stress, anxiety, depression, quality of Life • symptom checklist, concussion predictive and modifying factors) • SCAT3 • CBB • K-D test	• 64 (48%) reported symptoms on baseline SCAT. Sixteen concussed participants, 9 (56.3%), had a history of SRC. • CBB was consistent with clinically assessed recovery on 27 (51.9%) occasions. • K-D test was consistent with clinically assessed recovery on 32 (64%) occasions. Return to baseline for K-D test - 11 days(mean time) (±8.7, range 2-33 days). • 19 (38%) occasions, both the CBB + K-D test were consistent with the clinical assessment of recovery. On seven occasions, there was agreement on the presence of concussion, and on 12 occasions, recover agreement. • 10 (20%) occasions participants passed CBB and K-D when not deemed clinically recovered from concussion. 1 (2%) occasion, a participant failed CBB and K-D when they were deemed recovered from concussion. • CBB and K-D test results differed on 20 (40%) occasions. CBB agreed on 7 (14%) of occasions. K-D agreed with assessment-13 (26%) occasions.
Emery et al., 2021	To assess factors associated with clinical recovery after concussion in youth ice hockey players.	• Players with suspected SRC were referred to a sports medicine physician for diagnosis, and SCAT3/5 was completed. • Two accelerated failure time models are used to estimate days to RTP clearance. • Other covariates were time to physician first visit (≤7 and >7 days), age group (11-12, 13-14, and 15-17 years), sex, league type (body checking and no body checking), tandem stance (modified Balance Error Scoring System result ≥4 errors), number of previous concussions.	• Symptom scores • RTP clearance (days) • Time to first clinician visit • SCAT3/5 data • Time to clinical recovery was recorded as the time between concussion and physician clearance to RTP.	• The median time to clinical recovery was 18 days. Longer time to first physician visit (>7 days) (time ratio [TR], 1.637 [95% confidence interval (CI), 1.331-1.996]) and greater symptom severity (TR, 1.016 [95% CI, 1.012-1.020]) were predictors of longer recovery. • Longer time to first physician visit, headache (moderate/severe), and poorer tandem stance were predictors of longer recovery. • RTP longer for players with >7 days to assessment. • Poorer scores on tandem gait, higher symptom evaluation score, and greater headache severity were associated with longer time to clinical recovery.

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TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Kelleher et al., 2014	To implement standardised care via a mild traumatic brain injury (mTBI) clinic (pilot program to provide concussion evaluation and assist RTP) and survey players post-season.	• 405 students playing football were selected. • Athletes with SRC either attended a local healthcare provider or the mTBI clinic. Appointments included mTBI symptom screening + neurological exam. • Symptomatic athletes - rescreening occurred after the RTP algorithm specified interval, and, if appropriate, athletes were cleared for graded RTP. If symptoms persisted beyond 2 weeks, referral to a specialist was performed.	• IMPACT scores • ACE evaluation • Survey: concussion injury reporting and medical management journey.	• 17/28 students had a previous concussion history. The mean amount of time until RTP was 16.9 days. • 266 respondents to the survey. 40 (15%) reported mTBI symptoms during the season. Of the 15%, 9 (22.5%) did not report their symptoms to anyone, and 18 (45%). • Unreported mTBI episodes are lower (22.5%) than published self-reported mTBI rates.
Theme 4 – Individual accounts of concussion management in specific populations				
4.1 Chiropractic management				
Olson et al., 2018	To describe the chiropractic management and return-to-play of 3 student football players who had experienced a concussion.	• Concussion, neurological and musculoskeletal evaluation, computerised neurocognitive (ImPACT) and balance testing. • The course of treatment was initiated, consisting of: 1. Instrument-assisted soft tissue mobilization, 2. Myofascial release (MRT)Concussion. Spinal manipulative therapy (SMT) and therapeutic exercises were provided to help treat cervical spine symptoms and dysfunction.	• Symptomatology • ImPACT scores • SCAT3 • RTP	• **CASE 1: Final visit:** Memory composite (verbal, visual), visual motor composite, reaction time composite, and impulse control composite scores returned to baseline. RTP - 12 days. Monitored throughout the year - no injury/ symptom exacerbations. • **CASE 2 Final visit:** Completed RTP protocol + RTP (24 days) - no further setbacks. • **CASE 3 Follow-up:** Follow-up took place 12 days after the initial visit. The participant had been symptom-free since the day after his initial treatment and RTP. Computer neurocognitive test scores – baseline levels.
Hunt et al., 2018	Concussed skateboarder undergoing chiropractic treatment.	• Intervention: Chiropractic care. No control. Intervention included - Evaluated for subluxation and 'adjusted' where necessary, twice per week.	• Symptom relief was reported by the patient.	• 5th visit - patient reported overall 80% improvement and reported 'feeling freer'/ sight and breathing had improved. Ongoing 'sore head' when sneezing. • Reported resolution of pupillary light reflex testing and photophobia by the 8th visit.
4.2 Concussion and mental health				
Sherry et al., 2021	Presentation of a case of a high-achieving 18-year-old female athlete (Rower) and her transitioning concussion care to mental health care.	• Seen by a neuropsychologist in clinic 4 days post-injury. Ongoing referrals to a vestibular therapist. • Symptoms persisted, plus anxiety/mood clinical profile. • Referred to cognitive behavioral therapy (CBT) and psychiatry. • She declined the referral to counselling due to distress and time constraints. Commenced on sertraline medication. • Decided to return to full rowing participation as a return to activity was expected to improve her mental health.	• Symptoms: cognitive/ ocular-motor/ Headache/ vestibular/ Anxiety/ mood. • PCSS	• The participant had been on sertraline for approximately 2 months and reported feeling "back to normal." She reported resolution of all concussion symptoms. • Significant improvement in her mood, anxiety, and no further panic attacks. Full participation in rowing and passed formal exertion testing with the school athletic trainer. • Cleared for RTP and academic activities and discharged. Advised to remain on antidepressant under the guidance of a psychiatry and her family doctor. • 6 months after being discharged, she was continuing with sertraline and felt it made a "big difference in her anxiety."

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Tucker, DeCastro, and Brock 2019	To discuss two cases of post-concussion syndrome in adolescent athletes with a past personal or family history of attention-deficit/ hyperactivity disorder, anxiety, and depression, treated by a combination of cognitive behavioural therapy and medication, with ongoing persistent symptoms.	• **Case 1** - A 17-year-old male athlete (medical history of attention deficit/hyperactivity disorder (ADHD)) sustained an SRC while participating in football practice. • Amitriptyline 50 mg daily treatment was initiated for posttraumatic headaches and other associated symptoms. • **CASE 2 -** 16-year-old male with history of a simple febrile seizure during childhood + family history of posttraumatic stress disorder with depression. Followed the RTP protocol following a concussion. Further concussion sustained 1 month later. Return to school (RTS) was unsuccessful due to ongoing headaches, dizziness, and difficulty concentrating.	• Symptomatology • Mental health status	• **CASE 1:** Return to activity failed due to headaches and difficulty concentrating. The participant reported bullying. • Ongoing irritability, anxiety, and insomnia. Transitioned to home education. • Ongoing nystagmus, saccadic eye movements, impaired motor development, and vestibular impairment. New panic attacks (started on short-term lorazepam 1 mg). Did not attend RTS and instead gained employment in his family's landscaping business. • **CASE 2:** Difficulty with balance and right eye nystagmus. Transitioned to homebound education, started on amitriptyline. • Unsuccessful at the second RTS attempt at 5 months. Able to RTS after the school year. Ongoing depressive symptoms (commenced counselling and fluoxetine). Required hospitalization - mental health. • Developed grand mal seizures (started anti-epileptics.
Waldmeier-Wilhelm et al., 2019	To describe a case involving a 14-year-old girl who developed a pronounced and prolonged post-concussive syndrome and subsequent posttraumatic stress symptoms after (mild) traumatic brain injury	• Clinic presentation - worsening of school performance. 4 months before, involved in a snowboard accident (2-3 minutes of unconsciousness). • Evaluation in the ED was unremarkable, and the patient was discharged. • Persisting daily headache, concentration, memory problems, fatigue, dizziness, and blurred vision. • Neuropsychological assessment + physical therapy initiated. • Sports activities and school visits were reduced again, and oral magnesium was initiated. Relaxation therapy + psychological support continued. Occupational therapy declined.	• Symptomatology • Neurological exam • MRI Report	• 14 months after the injury, when returning to the injury site, a relapse of symptoms occurred. The patient complained about episodes of blurred vision, stomach aches, concentration problems, and sleep problems. Episodes of cardiac presyncope were observable. • Repeated neurological and neuropsychological examinations did not show any abnormalities. There were no obvious symptoms of depression. As the general physical examination was normal as well, no further additional investigations were initiated. • The relapse of symptoms was interpreted as a sign of posttraumatic stress, triggered by the confrontation with the location where the accident occurred (mountain area). Patient refused psychiatric evaluation-psychological coaching was continued.

(*Continued*)

TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
4.3 Specialist medical case reports/series				
Lunardini et al., 2009	Report on treated patient: Treating post-concussion symptoms in a young diabetic person	• Young male athlete with an SRC whilst playing football. Suffered headache, dizziness, partial loss of vision left eye, and right arm numbness. Initial high blood sugars (240 mg/dL). • Athlete RFP and within 30 minutes (dizziness and headache symptoms). The patient was reviewed by the physician and sent home with a diagnosed grade 2 concussion + post-injury instructions. • Concentration difficulties/ headaches. • 6 weeks - referred to a neuropsychologist.	• Symptoms reported • Initial high blood sugars • Concentration and delayed recall testing (Using the SAC test) • Neuropsychologist review (at 8 weeks)	• Concentration and delayed recall improved when tested over the following week. • Following Neuropsychologist review (at 8 weeks), headaches had reduced to once every three days and reported functioning 90-95% of normal. • The young athlete was cleared after 4 months, following completion of a controlled aerobic exertion test and resolution of all symptoms. In an interview with the participant at 4 years after the initial injury, he reported that it took 6 months to fully return to his normal 'thinking speed'. No long-term effects reported. • Known to have a history of poor blood glucose control.
Stiller-Ostrowski 2010	Case of a National Collegiate Athletic Association Division I men's lacrosse athlete with a fourth cranial nerve injury as the result of a minor traumatic blow	• Minor traumatic blow during lacrosse. Referred to neurology/ ophthalmology. MRI of the orbits was normal. • Diagnosed with contusion/ stretch injury to the oculomotor nerve. • Prognosis of full resolution of symptoms (3-4 weeks) and advised to continue to use the eye normally. • Visual disturbances not resolved by 4 weeks. A battery of tests was performed in week 5, and the original diagnosis was rejected. • Diagnosed with palsy of the right superior oblique muscle secondary to right CN IV palsy. Prognosis of full recovery 3 to 4 months postinjury.	• Symptoms • Injury risk • RTP clearance	• 5 months postinjury - No diplopia about 90% of the time (Double vision occurring in extreme left gaze). Diplopia did not have any functional implications. • The neuro-ophthalmologist informed the patient and his family of the risk of returning to high-velocity sports with even intermittent diplopia, but the patient received medical clearance to return to competitive lacrosse. • By 6 months post-injury, he reported subjective normal vision. At that time, his risk of reinjury was equivalent to his preinjury risk. The patient was referred for a custom-moulded mouthguard. • Able to return to full competition during the fall 2008 season and competed fully in both the fall 2008 and spring 2009 competitive seasons with no recurrence of symptoms. 16 months post-injury, the patient is back to his pre-injury level of competition.

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Bramley et al., 2012	To report on the effectiveness of steroids for severe posttraumatic headache, along with recommended treatment strategies for acute pain management and prevention.	• **Case 1:** 15-year-old with worsening symptoms. Standard 6-day methylprednisolone 4-mg dose pack initiated. Resulted in significant headache reduction/ improved mood. • Completed steroid taper/400 mg ibuprofen. Discontinue acetaminophen with codeine. • **CASE 2 -** A 10-year-old boy referred with severe headache, dizziness, and vomiting 21 days post SRC. • Ongoing pain, and a standard 6-day tapering methylprednisolone 4-mg dose pack was added. • 7 days later, symptoms returned. Amitriptyline increased to 50 mg, started 14-day methylprednisolone.	• Symptom reporting • medication use • Return to school/ physical activity.	• **CASE 1:** 13 days post injury, ongoing headache caused by activity resumption. Methylprednisolone completed. • Sleep remained disturbed, melatonin was added, plus increased trazodone. Continued gabapentin/ibuprofen. Instructed to start school on half days. • RTS full time at 8 weeks after injury - close to baseline with only occasional headache. Trazodone weaned to 50 mg, to discontinue in 1 week if sleep is resolved. • Melatonin/gabapentin was discontinued a few weeks later. • 12 weeks after the injury patient had returned to baseline. • **CASE 2:** After a 14-day tapering course of medication, subjective decrease in frequency/intensity of headaches and complete relief of emesis. The headache gradually resolved and did not return after the completion of the second course of steroids. • 11 weeks post injury, returned to school full time, increasing physical activity, and symptom-free.
McNally et al., 2024	To report on a case of worsening concussion symptoms and an MDT approach to care	• 16-year-old female who sustained a concussion falling off a horse, and who failed to respond to standard concussion care. • After 2 months of worsening symptoms, she was referred to an MDT clinic. • Interventions included: Stopping amitriptyline, continuing to take magnesium and riboflavin supplements; Physiotherapy – vestibular and neck treatment; Supervised exercise programme with an athletic trainer; PT; Advice on improving lifestyle (hydration and not skipping meals).	• Behaviour rating scales • SCAT5 symptom scale • PedsQL • NeuroQOL Sleep • Activities-Specific Balance Confidence Scale. • Neuropsychological testing	• Full recovery of symptoms at final treatment session (Visit 3 – 75 days post injury). • Continued to present with mild functional gait disturbance. • Cleared by neurologist to complete a gradual return to horse riding at 82 days post injury. • Patient continued on medications for her underlying anxiety and post-traumatic stress disorder (PTSD).
4.4 Normative return-to-play rehabilitation				
Gunter et al., 2018	Physical therapy management and adapted return-to-sport protocol for an equestrian athlete with history of multiple concussions.	• 14-year-old female with 3rd concussion in 3 years. • Return-to-riding protocol tailored. • 8 physical therapy sessions over 4 weeks for vestibular training, aerobic conditioning, and cervical/ core exercises, plus equestrian exercises.	• Symptom reporting • Dynamic visual acuity test • Joint position error • BESS	• Final evaluation: Patient reported no symptoms at rest, with exercise, or when testing the vestibular-ocular reflex. Improvements were noted in the dynamic visual acuity test, joint position error, and BESS, with changes in the BESS exceeding minimal detectable change. • The patient completed the full return-to-riding protocol in 8 weeks and returned to competition.

(*Continued*)

TABLE 2 - (*Continued*)

Authors	Study Aims/ Purpose	Methods/ Interventions	Primary Outcome Measure/s	Results
Marsh et al., 2013	Report on treated patient: Case report of young 14 year 14-year-old athlete with hockey hockey-related concussion	• Diagnosed with a mild concussion and discontinued hockey/ activity that exacerbated symptoms. • Patient advised to return for 1 1-week review.	• Symptoms reported • Follow-up attendance • RTP and symptom reporting.	• Symptoms: Feeling 'fuzzy' and frontal headache. Did not attend 1 week follow-up, but instead was reviewed 3 weeks later. • Completed the stages of RTP, with no significant symptoms reported. No timescale reported.

Discussion

The aim of this scoping review was to complete a systematic search of published primary research literature on the medical management, rehabilitation approaches, and outcome data for the concussed youth athlete across all stages of injury management. Following a rigorous search, we identified studies reporting a variety of intervention approaches and grouped these into four key themes. Thirty-six studies were included in the review, 14 studies reported on exercise, early activity and neuromuscular rehabilitation interventions, six studies reported on pitch-side management of concussion or ongoing monitoring/management of injured youth athletes, five studies reported on the use and outcomes of novel treatment interventions and 11 studies reported on individual case report accounts of concussion management in specific populations.

Exercise, activity, and neuromuscular training interventions

In this review, we found level 2 and 4 evidence (RCTs and cohort studies, respectively) that remaining active following a concussion was beneficial, provided that participants worked at a sub-symptom threshold (40,49,56,59). Relative rest and exercise interventions with a low aerobic exercise requirement, such as stretching programmes, were generally less effective at reducing symptoms and facilitating return to play (37,40). Generally, those who took fewer steps, or exercised vigorously had poorer outcomes than their counterparts working within a graded STEP (54). There was evidence to suggest that exercise sessions lasting more than 15 minutes reduced the risk of developing further post-concussion symptoms (29). This is particularly useful in planning and supporting youth athletes with their activity and exercise plans post-concussion, and the evidence found in this section of the review continues to support the safety and efficacy of early aerobic exercise interventions, provided the athlete is working at a sub-symptom threshold. In order to establish these thresholds, provocative exercise testing such as the Buffalo Concussion Treadmill test (BCTT) can be used. The evidence found in this review reported that completing such a test within 10 days post-concussive injury did not delay participant recovery and cardiovascular responses differed between control and SRC participants, but that the test was safe to administer (39,61). STEP programmes, alongside provocative aerobic exercise testing, were found to be safe and provided therapeutic benefits (35,61). By grading up exercise in a controlled and progressive manner, those with recent SRC were able to build up to tolerating 15 minutes of aerobic exercise by the final session in one study (60). Chan et al. reported that symptom exacerbation was limited to 24 hours, with resolution within this period, and the majority of exacerbations were self-limited to 15 minutes before resolution (60). This is particularly useful for those clinicians administering exercise interventions for concussed youth athletes, and provides evidence that symptom exacerbation is not an indicator to cease STEP interventions. Limited data were presented for neuromuscular training programmes, with two studies suggesting that NMT is safe and may provide longer-term benefits, such as reduced future sports-related injuries over future seasons (34,38). The evidence here may help clinicians develop post-concussion, future injury prevention programmes to support their athletes throughout future sporting seasons.

Pitch-side management approaches, sub-acute assessment, and monitoring

There were only six studies reporting on pitch-side management, ongoing assessment, and monitoring. Youth athletes whose symptoms arose after 15 minutes were more likely to have remained on the field of play, as opposed to those with a more rapid onset of symptoms. Those with delayed symptom presentation were slower to RTP following their concussion diagnosis (31-32,57). Immediate symptom recognition may not only be difficult for responsible pitch-side adults, but also for the youth athletes themselves. Symptoms of concussion, such as disorientation and confusion, may contribute to reduced injury reporting abilities. Concussion injuries remain Challenging to diagnose due to the heterogeneity of clinical presentations and the lack of definite diagnostic and objective tests. Concussion reporting from high school athletes to their respective coaches or responsible adults is poor, and those transitioning into college/university level sport, who have sustained previous concussions, are more likely to remain on the pitch following a future potential concussive injury (65). Athlete reporting behaviour is known to be a concern, with often a myriad of reasons for poor injury reporting. Coaches may also be limited in their concussion injury recognition and early pathway management, thus limiting effective identification, removal from play, and necessary onward medical management or referral (23,66). Furthermore, medical primary and secondary care clinicians' knowledge of concussion management serves as a barrier to best practice concussion care, often with a lack of specific concussion education as a precipitating factor (67,68). More basic medical management messaging, such as "if in doubt, sit them out" and "recognize and remove", has been targeted to support less experienced and knowledgeable stakeholders (24). However, what comes after this in terms of management is somewhat more ambiguous and will certainly rely upon more expert guidance and resources.

The use of the SCAT5 is reported in a number of studies in this review, and further research will likely include the use of the new SCAT6 (69). Further reliability and repeatability studies are warranted for this new assessment tool to ensure the most accurate clinical assessments are utilised, pitch and courtside. Clinical testing protocols such as the Cogstate Brief Battery (CBB) or King Devick (K-D) test have previously been developed for concussion injury assessment and monitoring, and played a role in clinical decision making. In this review, one study found that these testing approaches were unable to consistently provide accurate results for concussion assessment and monitoring, and the authors suggest that these assessment tools should not be used in isolation (64). Likewise, with the SCAT6, clinical judgment and expert assessment are required, and to date, no objective test offers a definitive diagnosis of concussion (27). A further study in the assessment and monitoring theme highlighted that delayed presentation to the clinic (>7 days) and greater symptom severity following a concussion resulted in protracted clinical recovery (55). It would be sensible to suggest that rapid, expert assessment, clinical impression, and treatment are commenced as quickly as possible after a suspected injury for the best health outcomes. Research into blood-based biomarkers for concussion diagnostics has been reported in the 2022 concussion consensus statement (27,70). With the evolution of healthcare technology, identifying, monitoring, and treating concussive injuries may become easier; however, we must ensure that scientific rigor backs any chosen management strategies before widespread implementation of such technologies occurs (71).

Novel treatment interventions

Novel treatment choices remain understudied; however, two studies in the review reported positive results for the use of a head/ neck cooling device for post-concussion symptoms. One study reported the effect of face cooling therapy on the parasympathetic system response. The head and neck cooling studies reported an earlier reduction in post-concussion symptoms within the earlier stages of treatment (36,50). The overall recovery trajectory for both the intervention arm and control group was similar, however, with similar symptom resolution by 1 month after commencing treatment. These results are preliminary and should be interpreted as such. Face cooling was found to have no significant effects on parasympathetic parameters in concussed versus control group athletes, yet there were notable blunted responses in HR and HRV for those with a previous concussion history. This adds to the scientific base on altered physiological parameters following concussive injuries (72). Whilst these results are promising for new concussion recovery or monitoring technology development, before widespread manufacture and use of such face or head-cooling technologies, we would expect the intervention to follow the Ideal, Development, Exploration, Assessment, and Long-term study (IDEAL) framework before conclusions are drawn (73).

The remaining study reported on the effects of hyperbaric oxygen therapy (HB02) for the treatment following concussion; however, the authors did not explore treatment efficacy (44). The results were suggestive of some clinical benefit; however, they were inconclusive due to the study design limitations. No adverse effects were reported, and future research may be warranted to explore HB02 as an alternative or complementary post-concussion treatment option.

Individual accounts of concussion management in specific populations

This review found a variety of case reports charting interventions and recovery, encompassing complex medical cases and situations where young athletes' mental health was impacted significantly. In the cases reporting on poor mental health, or persisting symptoms, inter-disciplinary team referral and collaboration were critical in the success of ongoing management, especially the involvement of psychological interventions (45,47,53,62). For those youth athletes with a mental health complaint in conjunction with or resulting from their post-concussive symptoms, the outcomes were generally poor (47,62). Whilst the majority of studies reported on in this review yielded clinical success, it was apparent that athletes requiring specialist psychological support experienced a more complex and incomplete recovery journey. Two studies in this section of the review discussed normative return to play approaches for youth athletes, adding little to the knowledge base for management approaches but potentially offering clinicians a reference guide for management (41,60). Three studies reported on specialist medical cases including athletes requiring: steroid medication for persistent post-concussive headaches (48); ophthalmology review and input for a suspected cranial nerve palsy (46), and medical input plus academic protections for an athlete with poor blood glucose control and concussion injury (42). Two studies reported on chiropractic interventions and may again provide a guide for chiropractors in practice (43,63). Such case reports in this theme provide narrative accounts of the management of specific individuals and offer little to the research base regarding generalisable management approaches.

Strengths and Limitations

The strengths of this scoping review are the comprehensive nature of the review process, where a robust cross-database search was completed (eight databases) and manual screening of included manuscripts. There are various limitations to this work. Despite this and using pragmatic search terms, it is possible that relevant articles were missed. We suggest that any further such primary data as to the graded return-to-play and outcomes for concussed youth athletes be potentially recorded and not readily available to the research community and clinicians. A significant proportion of studies found in this review were case reports, and as such, we accept the risk of participant selection and reporting bias. Furthermore, these cases may not be truly representative of the wider management of concussion youth sport, as published case reports usually pertain to particularly interesting or challenging presentations, which was the case in this review. Three case reports included in the review discussed novel treatment choices, including hyperbaric O_2 therapy and head/ neck cooling devices. We accept that these devices may not be readily available in certain settings, due to financial or logistical restraints, and therefore would not be generalisable treatment choices. The evidence for the efficacy of these devices has also not yet been demonstrated. There was also a lack of studies focusing on female-only youth athletes, so sports that predominantly females participate in have been under-represented. No studies were found that reported on management approaches for para-sporting youth athletes. We excluded non-English language studies, which also represents a limitation of this study. Notably, the majority of studies found were from the North American continent, where health care management may differ, and thus, selected management approaches may not be widely generalisable.

Implications for clinicians and researchers

Our scoping review provides a foundation of all primary data sources reporting on the outcome of specified treatment interventions for the concussed youth athlete. We would hope that our work founds the basis for routine and evidence-based management approaches for such athletes, and where we have identified primitive research fields and literature gaps, we would hope for future researchers to target these.

Conclusion

This review, within the constraints of the selected study parameters, synthesises the available primary research data on medical management approaches for concussed youth athletes worldwide. The review highlights the benefits of sub-threshold activity and exercises for concussive symptom resolution and reducing the risk of developing PCS, and may guide physiotherapists and other healthcare practitioners to prescribe threshold exercise to injured youth athletes. Limited data exists for alternative treatment strategies, and we did not find any data sources reporting on primary and secondary medical care management approaches. Nor a particularly expansive literature base evidencing physiotherapy interventions. Despite a focus on graded return to sport (GRTS) protocols in recent guidance publications, no study reported on a monitored GRTS intervention and outcomes (17,18,19,21). Limited data was presented on return-to-learn strategies for the concussed youth athlete, and was often only presented in case reports, where return to school failed. The published primary research data that reports outcomes of medical management approaches for the concussed youth athlete remains limited to exercise and activity recommendations and sub-threshold exercise programmes. Few data exist for alternative management approaches, particularly in settings where resources would not allow for exercise threshold testing and monitoring. Case reports and series saturated this review, and they add little to the generalizable knowledge base for youth concussion management approaches. Research and data published from outside the USA and Canada remain significantly limited. Concussed female youth athletes remain understudied in isolation. Large-scale and multicenter cohort injury data reporting would improve future transparency of youth adolescent athlete concussion monitoring, rehabilitation, and outcome data would provide a vital insight into injury management and help guide future research into concussion management strategies.

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Study registration: Registered on the open science framework – CrossRef

References

1. Russell ER, Mackay DF, Stewart K, et al. Association of field position and career length with risk of neurodegenerative disease in male former professional soccer players. JAMA Neurol. 2021;78(9):1057-1063. CrossRef PubMed
2. Russell ER, Mackay DF, Lyall D, et al. Neurodegenerative disease risk among former international rugby union players. J Neurol Neurosurg Psychiatry. 2022;93(12):1262-1268. CrossRef PubMed
3. Kelly KD, Lissel HL, Rowe BH, et al. Sport and recreation-related head injuries treated in the emergency department. Clin J Sport Med. 2001;11(2):77-81. CrossRef PubMed
4. McCrory P, Feddermann-Demont N, Dvořák J, et al. What is the definition of sports-related concussion: a systematic review. Br J Sports Med. 2017;51(11):877-887. CrossRef PubMed
5. Giza CC, Kutcher JS. An introduction to sports concussions. Continuum (MinneapMinn). 2014;20 (6 Sports Neurology): 1545-1551. CrossRef PubMed
6. Brody DL. Concussion care manual. Oxford University Press; 2019:177. CrossRef
7. Bey T, Ostick B. Second impact syndrome. West J EmergMed. 2009;10(1):6-10. PubMed
8. Cassidy JD, Carroll LJ, Peloso PM, et al. WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J RehabilMed. 2004;36(43)(suppl):28-60. CrossRef PubMed
9. Veliz P, McCabe SE, Eckner JT, et al. Prevalence of concussion among US adolescents and correlated factors. JAMA. 2017;318(12):1180-1182. CrossRef PubMed

10. Meehan WP III, Mannix R. Pediatric concussions in United States emergency departments in the years 2002 to 2006. J Pediatr. 2010;157(6):889-893. CrossRef PubMed
11. Billette JM, Janz T. Injuries in Canada: Insights from the canadian community healthy survey. Statistics Canada. 2021. Online (Accessed October 2024).
12. McKeever CK, Schatz P. Current issues in the identification, assessment, and management of concussions in sports-related injuries. Appl Neuropsychol. 2003;10(1):4-11. CrossRef PubMed
13. Giza CC, Hovda DA. The neurometabolic cascade of concussion. J Athl Train. 2001;36(3):228-235. PubMed
14. Shrey DW, Griesbach GS, Giza CC. The pathophysiology of concussions in youth. Phys Med Rehabil Clin N Am. 2011;22(4):577-602, vii. CrossRef PubMed
15. McGroarty NK, Brown SM, Mulcahey MK. Sport-related concussion in female athletes: a systematic review. Orthop J Sports Med. 2020;8(7):2325967120932306. CrossRef PubMed
16. Ono KE, Burns TG, Bearden DJ, et al. Sex-based differences as a predictor of recovery trajectories in young athletes after a sports-related concussion. Am J Sports Med. 2016;44(3):748-752. CrossRef PubMed
17. UK Government. UK Concussion Guidelines for non-elite (grassroots) sport. Landmark concussion guidance for grassroots sport published - GOV.UK.2023. Online
18. AUS GOV – concussionguidance. Concussion and Brain Health Position Statement 2024. Online (Accessed October 2024).
19. Accident Compensation Corporation. SPORT CONCUSSION IN NEW ZEALAND: NATIONAL GUIDELINES. 2024. Online (Accessed October 2024).
20. McArdle D, DeMartini A, Kim S, et al. 'It isn't my area.' Coaches' awareness of concussion protocols in Scottish youth football. Scott Aff. 2021;30(1):53-73. CrossRef
21. Sport Scotland. If in Doubt, Sit Them Out. Online (Accessed October 2024)
22. Murray IR, Murray AD, Robson J. Sports concussion: time for a culture change. Clin J Sport Med. 2015;25(2):75-77. CrossRef PubMed
23. Parry K. World Cup concussion rules may be putting players' lives at risk. The Conversation. 2022. Online (Accessed October 2024).
24. Patricios JS, Schneider KJ, Dvorak J, et al. Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport-Amsterdam, October 2022. Br J Sports Med. 2023;57(11):695-711. CrossRef PubMed
25. Piedade SR, Hutchinson MR, Ferreira DM, et al. The management of concussion in sport is not standardized. A systematic review. J Safety Res. 2021;76:262-268. CrossRef PubMed
26. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467-473. CrossRef PubMed
27. World Health Organization. Adolescent health. World Health Organization. Online (Accessed October 2024).
28. Melnyk BM, Fineout-Overholt E. Evidence-based practice in nursing & healthcare: a guide to best practice (Fifth edition). Wolters Kluwer. 2023 (Adapted). Online (Accessed October 2024).
29. Neely LM, Smulligan KL, Wingerson MJ, et al. The association between sleep and physical activity with persisting post-concussion symptoms among adolescent athletes. PM R. 2023;15(9):1122-1129. CrossRef PubMed
30. Kelleher E, Taylor-Linzey E, Ferrigno L, et al. A community return-to-play mTBI clinic: results of a pilot program and survey of high school athletes. J PediatrSurg. 2014;49(2):341-344. CrossRef PubMed
31. Zynda AJ, Worrall HM, Sabatino MJ, et al. Continued play following adolescent sport-related concussion: prospective data from the North Texas Concussion Registry (ConTex). Appl Neuropsychol Child. 2022;11(4):740-751. CrossRef PubMed
32. Elbin RJ, Sufrinko A, Schatz P, et al. Removal from play after concussion and recovery time. Pediatrics. 2016;138(3):e20160910. CrossRef PubMed
33. Seehusen CN, Wilson JC, Walker GA, et al. More physical activity after concussion is associated with faster return to play among adolescents. Int J Environ Res Public Health. 2021;18(14):7373. CrossRef PubMed
34. Howell DR, Seehusen CN, Walker GA, et al. Neuromuscular training after concussion to improve motor and psychosocial outcomes: a feasibility trial. PhysTher Sport. 2021;52:132-139. CrossRef PubMed
35. Worts PR, Mason JR, Burkhart SO, et al. The acute, systemic effects of aerobic exercise in recently concussed adolescent student-athletes: preliminary findings. Eur J ApplPhysiol. 2022;122(6):1441-1457. CrossRef PubMed
36. Congeni J, Murray T, Kline P, et al. Preliminary safety and efficacy of head and neck cooling therapy after concussion in adolescent athletes: a randomized pilot trial. Clin J Sport Med. 2022;32(4):341-347. CrossRef PubMed
37. Leddy JJ, Haider MN, Ellis MJ, et al. Early subthreshold aerobic exercise for sport-related concussion: a randomized clinical trial. JAMA Pediatr. 2019;173(4):319-325. CrossRef PubMed
38. Howell DR, Seehusen CN, Carry PM, et al. An 8-week neuromuscular training program after concussion reduces 1-year subsequent injury risk: a randomized clinical trial. Am J Sports Med. 2022;50(4):1120-1129. CrossRef PubMed
39. Leddy JJ, Hinds AL, Miecznikowski J, et al. Safety and prognostic utility of provocative exercise testing in acutely concussed adolescents: a randomized trial. Clin J Sport Med. 2018;28(1):13-20. CrossRef PubMed
40. Leddy JJ, Master CL, Mannix R, et al. Early-targeted heart rate aerobic exercise versus placebo stretching for sport-related concussion in adolescents: a randomised controlled trial. Lancet Child Adolesc Health. 2021;5(11):792-799. CrossRef PubMed
41. Gunter KB, Shields CJ, Ott SD, et al. Rehabilitation of an adolescent equestrian athlete with a history of multiple concussions: a case report describing an adapted Return-to-Sport protocol. J Orthop Sports Phys Ther. 2018;48(12):934-942. CrossRef PubMed
42. Lunardini DJ, Berg CL, Perriello VA Jr, et al. Persistent postconcussion symptoms in a young diabetic athlete: a case review. Athl Train Sports Health Care. 2009;1(1):37-40. CrossRef
43. Olson H, Tunning M, Lindholm S. Chiropractic management of three young athletes with concussion. Chiropractic Journal of Australia (Online). 2018;46(1):29-47. CrossRef
44. Roby PR, Lynall RC, Cools MJ, et al. Hyperbaric oxygen therapy to treat acute sport-related traumatic brain injuries: a case series. Int J AthlTher Train. 2021;26(3):140-144. CrossRef
45. Sherry NS, Feder A, Pan R, et al. Transitioning concussion care to mental health care: a case study of an elite athlete. Case Stud Sport Exerc Physiol. 2021;5(1):135-144. CrossRef
46. Stiller-Ostrowski JL. Fourth cranial nerve palsy in a collegiate lacrosse player: a case report. J Athl Train. 2010;45(4):407-410. CrossRef PubMed
47. Tucker Price S, DeCastro AO, et al. Post-concussion syndrome and pre-existing mood disorder: A case report. Int J PsychiatryMed. 2019;54(3):163-171. CrossRef PubMed
48. Bramley H, Melinosky C, Silvis M, et al. Pediatric post-traumatic headache: two cases using steroids as abortive therapy. Pediatr Emerg Care. 2012;28(10):1081-1084. CrossRef PubMed

49. Chrisman SPD, Whitlock KB, Mendoza JA, et al. Pilot randomized controlled trial of an exercise program requiring minimal in-person visits for youth with persistent sport-related concussion. Front Neurol. 2019;10:623. CrossRef PubMed
50. Smith MA, McNinch NL, Chaney D, et al. Reduced Concussion Symptom Burden in Early Adolescent Athletes Using a Head–Neck Cooling Device. Clin J Sport Med. 2022;10-1097. CrossRef PubMed
51. Haider MN, Chizuk HM, Johnson BD, et al. Parasympathetic responses to face cooling in adolescents with sport-related concussion and after clinical recovery. Neurotrauma Rep. 2025;6(1):93-105. CrossRef PubMed
52. Miller SM, Zynda AJ, Sabatino MJ, et al. A pilot randomized controlled trial of docosahexaenoic acid for the treatment of sport-related concussion in adolescents. ClinPediatr (Phila). 2022;61(11):785-794. CrossRef PubMed
53. McNally KA, Shiplett KM, Davidson AM, et al. Case study: neuropsychology-informed brief intervention for persisting symptoms after pediatric concussion in a multi-disciplinary clinic setting. J PediatrNeuropsychol. 2024;10(4):1-8. CrossRef
54. Lishchynsky JT, Rutschmann TD, Toomey CM, et al. The association between moderate and vigorous physical activity and time to medical clearance to return to play following sport-related concussion in youth ice hockey players. Front Neurol. 2019;10:588. CrossRef PubMed
55. Emery CA, Warriyar KV, Black AM, et al. Factors associa zted with clinical recovery after concussion in youth ice hockey players. Orthop J Sports Med. 2021;9(5):23259671211013370. CrossRef PubMed
56. Gagnon I, Grilli L, Friedman D, et al. A pilot study of active rehabilitation for adolescents who are slow to recover from sport-related concussion. Scand J Med Sci Sports. 2016;26(3):299-306. CrossRef PubMed
57. Olson A, Ellis MJ, Selci E, et al. Delayed symptom onset following pediatric sport-related concussion. Front Neurol. 2020;11:220. CrossRef PubMed
58. Chan C, Iverson GL, Purtzki J, et al. Safety of active rehabilitation for persistent symptoms after pediatric sport-related concussion: a randomised controlled trial. Arch PhysMedRehabil. 2018;99(2):242-249. CrossRef PubMed
59. Micay R, Richards D, Hutchison MG. Feasibility of a post-acute structured aerobic exercise intervention following sport concussion in symptomatic adolescents: a randomized controlled study. BMJ Open Sport ExercMed. 2018;4(1):e000404. CrossRef PubMed
60. Marsh AM, Fraser D, Marsh JP. Management of concussion in the pediatric patient. J Pediatr Health Care. 2013;27(6):499-504. CrossRef PubMed
61. Morissette MP, Cordingley DM, Ellis MJ, et al. Evaluation of early submaximal exercise tolerance in adolescents with symptomatic sport-related concussion. Med Sci Sports Exerc. 2020;52(4):820-826. CrossRef PubMed
62. Waldmeier-Wilhelm S, Studer M, Weisstanner C, et al. Mild traumatic brain injury: striking postconcussion symptoms due to inadequate management. Pediatr Emerg Care. 2019;35(6):e99-e103. CrossRef PubMed
63. Hunt BB, Holt K, Cade A, et al. Improvement in concussion symptoms of headache, poor concentration and photophobia in a 13-year-old male receiving chiropractic care: a case report. J Clin Chirop Pediat. 2018;1389. Online (Accessed October 2024)
64. Cosgrave C, Fuller C, Kung S, et al. A comparison of clinical assessment with common diagnostic tools for monitoring concussion recovery in adolescent rugby union players. PhysTher Sport. 2023;61:165-171. CrossRef PubMed
65. Register-Mihalik JK, Guskiewicz KM, McLeod TCV, et al. Knowledge, attitude, and concussion-reporting behaviors among high school athletes: a preliminary study. J Athl Train. 2013;48(5):645-653. CrossRef PubMed
66. Feiss RS, Lutz M, Moody JR, et al. A systematic z review of coach and parent knowledge of concussion. J Concussion. 2020;4. CrossRef
67. Zonfrillo MR, Master CL, Grady MF, et al. Pediatric providers' self-reported knowledge, practices, and attitudes about concussion. Pediatrics. 2012;130(6):1120-1125. CrossRef PubMed
68. Jervis CG, Adams SA, Fawkner S, et al. Concussion education in medical students studying in Scotland: an assessment of knowledge and future needs. Brain Inj. 2022;36(9):1196-1203. CrossRef PubMed
69. Echemendia RJ, Brett BL, Broglio S, et al. Introducing the Sport Concussion Assessment Tool 6 (SCAT6). Br J Sports Med. 2023;57(11):619-621. CrossRef PubMed
70. Tabor JB, Brett BL, Nelson L, et al. Role of biomarkers and emerging technologies in defining and assessing neurobiological recovery after sport-related concussion: a systematic review. Br J Sports Med. 2023;57(12):789-797. CrossRef PubMed
71. McKeever T, Hamilton DF. Is it scientifically valid, sensible, or safe to use biomarkers to diagnose concussion? BJSM Blog. 2023. Online (Accessed October 2024).
72. Kamins J, Bigler E, Covassin T, et al. What is the physiological time to recovery after a concussion? A systematic review. Br J Sports Med. 2017;51(12):935-940. CrossRef PubMed
73. Beard D, Hamilton D, Davies L, et al. Evidence-based evaluation of practice and innovation in physical therapy using the IDEAL-physio framework. PhysTher. 2018;98(2):108-121. CrossRef PubMed