Contemporary diagnosis and management of mild TBI (concussions): What you need to know

Joseph C. Panzera, DO, Olivia E. Podolak, MD, *and*
Christina L. Master, MD, FAAP, CAQSM, FACSM, FAMSSM, *Philadelphia, Pennsylvania*

ABSTRACT: Concussion is a common injury in children and adolescents and is a form of mild traumatic brain injury that surgeons will see in their acute care practice. With a rapidly changing evidence base for diagnosis and management, we will focus on the importance of timely identification and diagnosis, as well as the early initiation of active management of pediatric concussion immediately after injury through recovery. This approach involves the application of targeted therapies for specific deficits identified after concussion, addressing the individual pattern of symptoms experienced by patients following concussion. We will review what is known about the underlying pathophysiology that drives the clinical manifestations of concussion, the targeted clinical assessments that can both aid in the diagnosis of concussion, as well as drive the active rehabilitation of deficits seen after concussion. The standardized approach to the return to activities will also be described, including return to learning and sports. (*J Trauma Acute Care Surg.* 2024;96: 865–869.

KEY WORDS: Concussion; mild traumatic brain injury; management; pediatric; adolescent.

Concussion, a form of mild traumatic brain injury, or mTBI, is a common childhood injury impacting millions of children and adolescents annually in the United States, frequently occurring in sports and recreational settings.[1,2] Over the past decade, concussion evaluation and management have become an important area of interest across many medical specialties that care for patients with concussions. Clinicians caring for pediatric and adolescent patients with concussion are often faced with the challenge of timely diagnosis, as well as initiation of management, based on the most up-to-date evidence. Concussion is a complex injury, often requiring a multi-disciplinary approach with specialized assessments and treatment modalities. Clinicians often must tailor treatment plans to the individual, often including recommendations for symptom management during recovery, for gradual return to academic activity, gradual return to physical activity, and sometimes rehabilitative therapies, for the vestibular and vision systems. In addition, medical management for symptoms such as post-traumatic headache, as well as behavioral and cognitive therapies may be indicated. We will focus on the importance of timely diagnosis and early initiation of a multimodal active management approach to pediatric concussion through recovery.

Epidemiology and Clinical Pathophysiology

Concussion impacts an estimated 1.4 million children and adolescents annually,[1,2] with the overall incidence of sport-related concussion ranging from 0.1 to 21.5 per 1000 athletic exposures.[3] Recent estimates place the overall incidence of pediatric concussion at about 538 per 100,000 patients per year.[4] A study by Yard and Comstock estimated that the overall rate of concussions per year accounted for approximately 9% of all high school athletic injuries.[5] This study evaluated 100 high schools for more than 3 years and found 1308 concussions during 5,627,921 athletic exposures, resulting in an estimate of 395,274 concussions per year in US high school athletes across 9 different sports, including football, boys' and girls' soccer, volleyball, boys' and girls' basketball, wrestling, baseball, and softball. Girls' soccer and girls' basketball had the highest rates of concussions with 15.1% and 11.7%, respectively.[6]

The clinical manifestations of concussion occur due to a complex pathophysiological process affecting the brain without gross anatomic lesions. This injury is induced by biomechanical forces transmitted to the brain, resulting in neuronal dysfunction.[7] Following the injury, a complex biological process, known as the metabolic cascade, results in disruptions to the neuronal cell homeostasis within the brain. It has been hypothesized that the disruption of neuronal cells, and ultimately, mitochondrial dysfunction, causes the symptoms experienced by patients who have sustained a concussion. When neuronal cells are injured, they become hyperglycolytic, drastically increasing the brain's demand for glucose and oxygen. Due to the physiologic response to injury, cerebral blood flow is not increased sufficiently to meet the metabolic needs of the injured brain, resulting in a metabolic mismatch within the brain.[8] The resultant combination of mitochondrial dysfunction, metabolic mismatch, and neuronal cell injury, result in the manifestation of concussion symptoms experienced after injury.

Physical Examination and Diagnosis

Common clinical imaging modalities, such as computed tomography and magnetic resonance imaging, while useful in excluding more serious traumatic brain injuries requiring neurosurgical intervention, do not contribute to the diagnosis of concussion.[9] It is important to recognize potential red flags in youth presenting with head injury, such as altered mental status,

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From the Sports Medicine and Performance Center, (J.C.P.); Center for Injury Research and Prevention (O.E.P.); and Sports Medicine and Performance Center, Center for Injury Research and Prevention (C.L.M.), Children's Hospital of Philadelphia, Philadelphia, Pennsylvania.

Address for correspondence: Christina L. Master, MD, FAAP, CAQSM, FACSM, FAMSSM, Sports Medicine and Performance Center, Center for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, PA; email: masterc@chop.edu.

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seizures, limb paralysis or paresthesia, repeated emesis, or discharge from the ears or nose after injury. Such individuals should be referred for emergency evaluation and possible imaging in order to evaluate for more serious traumatic injury to the brain. While concussion research has made significant strides in the last decade with the goal of identifying biomarkers, concussion diagnosis remains a clinical one, relying on clinical judgment. When a patient presents with a head injury, clinicians should obtain a detailed history, including mechanism of injury, onset of symptoms after the injury, symptom type and burden, previous concussion history, and any co-occurring conditions. Risk factors for prolonged recovery after concussion in the pediatric population include concussion history, female sex, adolescent age and certain comorbidities including, certain visual conditions (i.e., amblyopia, strabismus, convergence insufficiency, etc.), history of migraines, attention-deficit/hyperactivity disorder (ADHD), learning disabilities, anxiety and depression.[10–13]

Once obtained, the clinician should proceed with a symptom assessment and physical examination. Validated tools commonly utilized for symptom assessment are the Post-Concussion Symptom Scale (PCSS), validated in children 11 years and older, or the SCAT Symptom Inventory, or Post-Concussion Symptom Inventory (PSCI) self-report, both with a Child version for children 5 years to 12 years of age and another for adolescents 13 years or older.[14] The PCSI and the SCAT symptom inventory assess 22 concussion symptoms on a severity scale of 0 to 6, with symptoms grouped into four categories, cognitive, emotional, fatigue, and physical, which can help inform the concussion management plan.

Visual and vestibular abnormalities are common after concussion.[15–20] As a result, the Consensus Statement on Concussion in Sport guidelines recommend the use of standardized assessment tools for concussion diagnosis, including an evaluation of vision, vestibular function, and balance. The visiovestibular examination (VVE) is a validated tool that has been shown to be a useful diagnostic and prognostic tool in pediatric concussion.[21–25] Visual and vestibular deficits at initial presentation have been associated with an increased risk of prolonged recovery and the development of persistent post-concussive symptoms (PPCS).[10,19] The VVE, validated in children as young as 6 years of age, is comprised of a suite of visual and vestibular tasks, including smooth pursuit, saccades, angular vestibulo-ocular reflex, near point of convergence, monocular accommodation, and a complex tandem gait assessment,[25] which consists of four conditions, walking heel-to-toe in a straight-line forward with eyes open and closed and backward with eyes open and closed, and has been found to be more sensitive and specific in its discriminatory ability compared with a device-based balance assessment[26]

Acute Management

The majority of children and adolescents recover from concussion within 4 weeks, but it is a heterogeneous injury requiring individualized care plans to address specific deficits noted on physical examination, reported symptom burden, and past medical history of each patient. While individualized care plans will vary, acute management of concussion is consistent in recommending relative cognitive and physical rest for the first 48 hours after injury which may include a brief absence from school, avoiding activities with risk of re-injury, and reduced screen time.[2,27] Children and adolescents during this acute period following concussion are vulnerable to re-injury and sequelae, including prolonged symptoms and slower recovery. Despite the role of rest in the recovery process, complete rest is not recommended and gradual return to both cognitive and physical activity should begin after the 48-hour period after injury. As strict rest and prolonged rest have been associated with longer recovery and increased risk for prolonged concussion symptoms, patients are advised to begin slow return to daily activities, such as school attendance with adjustments and support, and light aerobic physical exercise after a 48-hour rest period.[21,28] Physical activity should be increased in a step-wise fashion, as tolerated, and may be done under the supervision of an athletic trainer, sport-related who can monitor the return to play (RTP) process and reduce the risk of contact, collision, or other injury during this recovery time period.

Management of concussion involves symptom management and when task modification is not sufficient, referral to a specialist with experience with concussions, such as a sports medicine practice, for further targeted treatment of vestibular or visual deficits may be indicated. Emerging evidence supports early identification of patients with timely referral to sports medicine specialty care for multi-modal and active management improves time to recovery.[29,30]

Return to Learn and Return to Sports

Re-integration into the academic setting should be the primary focus for all pediatric patients diagnosed with a concussion and requires clinicians to address any visio-vestibular deficits, specifically convergence insufficiency and accommodative insufficiency, or motion sensitivity, and their subsequent potential impact on school activities. A Return to Learn (RTL) guide, such as the one outlined in Table 1.[2] below, is helpful for managing the school re-entry process and can be implemented early in the recovery process, following acute management with 24 hours to 48 hours of relative rest following the injury. Early incorporation of academic accommodations after injury to account for symptom burden and visual deficits are recommended for use in the school re-entry process[2,31,32] and requires engaging school administration and teachers. Academic accommodations allow for a gradual increase in school participation through task modification, and pacing breaks to decrease symptom exacerbation, and reducing visual workload, using preprinted school materials with larger font sizes and double spacing, photocopied notes, or audio recordings of class materials. Extra time for preparation for and completion of schoolwork and test-taking while the child recovers from concussion is also a key component of these academic adjustments after a concussion. Focusing on academic work in core subjects and excusing nonessential work, while allowing for breaks throughout the school day in a quiet environment is a helpful tool to help manage cognitive and visual loads and symptom exacerbation while increasing and maintaining school participation.

To guide clinicians and healthcare providers in safely returning youth athletes to sport, the Consensus Statement on Concussion in Sport recommends a structured RTP protocol. A stepwise process comprised of six steps, beginning with aerobic exercise and progressing to sport-specific activities and eventually full contact practice. Athletes must be concussion symptom-free for a 24-hour period at each step before advancing

TABLE 1. Sample Return to Learn Protocol

Step		Goal
1	Daily activities that do not result in significant exacerbation of concussion symptoms: some reading, minimizing screen time, 5- to 15-min periods with gradual increase	Gradual return to school activities
2	School activities: gradual increase in homework, light reading, or other cognitive activities	Increase cognitive work
3	Return to school with support: gradual re-introduction of schoolwork, starting with reduced workload and pacing breaks as needed	Further increase academic activities
4	Return to school full-time: gradual progression to full school activities, further increase in cognitive work	Return to full academic activities
5	Remove accommodations: full days of school and re-introduction of tests and quizzes	Complete make-up schoolwork and complete transition back to full academic activities

Adapted from the 6th Consensus Statement Graduated Return-to-Learn Protocol.[2]

to the following step. If any concussion symptoms return while progressing through the protocol, the athlete repeats the current level after an additional 24 hours before attempting to progress again. Trained healthcare providers should manage youth athlete progression through the RTP protocol, gauging readiness to return to sport and accounting for factors which may impact their symptom burden and recovery trajectory, such as under-reporting of symptoms by athletes wanting to return to sport participation as soon as possible or slower progression due to pre-existing co-occurring conditions (i.e., anxiety, depression, migraines).[33] Studies have also shown an increased risk for musculoskeletal injury following concussion, highlighting the importance of clinical supervision of the return to sport process to monitor athlete readiness and minimize injury risks.[34] The full step-wise RTP protocol can be found below in Table 2.[2]

Rehabilitation and Long-Term Management

The majority of children and adolescents recover from concussion within 4 weeks; however, up to one-third may experience persistent symptoms beyond that timeframe and benefit from targeted therapeutic approaches. Evidence has shown the utility of aerobic exercise in decreasing symptom burden, improving time to recovery, and return to sport by improving cerebral blood flow and improved regulation of the autonomic nervous system.[35] Evidence indicates that aerobic activity that only mildly exacerbates concussion symptoms is safe and effective in shortening time to recovery and reducing the risk for persistent postconcussion symptoms.[36] Adherence to an individualized sub-symptom exercise prescription within the first week following injury was associated with faster recovery from sport-related concussion in adolescent athletes.[37]

As discussed in the earlier sections, a detailed vision history and comprehensive visual evaluation can help clinicians identify a subset of patients with persistent visual symptoms or difficulties with the school re-entry process requiring referral for targeted therapies. Vestibular and vision therapies have become increasingly incorporated into concussion management protocols over the last decade. Deficits in saccades, angular gaze stability, and balance identified on the visio-vestibular examination can aid clinicians in identifying patients who may require vestibular rehabilitation. Vestibular therapy involves targeted exercises and tasks aimed at re-training the system that manages motion sensitivity for patients. A home exercise program, targeting horizontal and vertical saccades and angular ocular reflex can be initiated in the acute management phase for concussion and has been shown to be effective in lowering symptom burden and improving visio-vestibular function in pediatric concussion.[38] If further intervention is required, formal vestibular therapy may be of benefit and individualized vestibular therapy care plans under the supervision of a specialized physical therapist in vestibulopathies are recommended. Rehabilitation focuses on eye coordination and balance function through targeted exercises, progressing in difficulty to gradually increase motion tolerance and decrease symptoms while returning the patient to their preinjury levels of function. Addressing these deficits has been shown to help patients decrease recovery time.[39,40]

When visual symptoms persist, referral for formal rehabilitation of the visual system may be recommended. This therapeutic

TABLE 2. Graduated RTP

Step	Activity Level at Step Within RTP	Goal
1	Daily activity that does not significantly exacerbate symptoms	Gradual reintroduction of physical activity that does not have risk of head injury
2	Light intensity aerobic activity: goal heart rate around 55% of maximum	Increase heart rate and further progress physical activity
3	Moderate intensity aerobic activity: goal heart rate around 70% of maximum	Further increase heart rate and progress physical activity
4	High intensity aerobic activity: weight-lifting and/or aerobic activity greater than or equal to 70% of maximum	Resume usual intensity of exercise
5	Noncontact: sport-specific practice	Incorporate coordination and cognitive load tasks combined with exercise
6	Full contact: sport-specific practice	Assess for ability to safely and fully participate in athletic activity

Table adapted from the 6th Consensus Statement Graduated Return-to-Play Protocol.[2]

modality helps identify and treat underlying vision abnormalities that may be related to slow recovery, including difficulties with school performance and significant visual symptom burden. Patients with persistent accommodative and convergence insufficiency on physical examination may benefit from the incorporation of this targeted therapy into the concussion treatment plan. Rehabilitation of the binocular visual system can help mitigate persistent symptoms and increase visual stamina after concussion.

Additional compounding factors influencing concussion recovery are mood and mental well-being. Pediatric and adolescent patients with underlying mood disorders, such as depression, anxiety, bipolar disorder, and/or ADHD have been found to experience prolonged recovery from concussion due to increased difficulty managing and coping with symptoms.[41] In a patient with significant mood symptom burden, referral for behavioral therapy is warranted.[42–44] Behavioral health specialists, such as psychologists and psychiatrists, may be utilized to treat mood disorders and reduce the impact that underlying mood disorders have in concussion recovery using a combination of approaches that may include cognitive behavioral therapy and/or pharmacotherapy.

Children with persistent symptoms and academic decline following concussion may be impacted by undiagnosed or exacerbated underlying learning issues, such as ADHD or dyslexia, and may have difficulty with returning to pre-injury academic performance. When presented with a patient experiencing academic decline, referral to neuropsychology should be considered for a comprehensive assessment of executive function. Pediatric neuropsychologists are trained in assessing, diagnosing, supporting, and rehabilitating children with cognitive, learning, neurological, or psychiatric disorders.[45] While the availability of neuropsychology is often limited, neuropsychologic testing can be helpful in identifying any underlying or exacerbation of a neurocognitive disorder requiring further therapeutic support (i.e., medication or speech or cognitive therapy).

The role of medication use in concussion management is primarily for symptom management and lacks evidence to support widespread use.[46] However, when sleep disturbances are reported with concussion, short-term melatonin use may be beneficial. Melatonin is well-tolerated and can be considered for short-term treatment in pediatric patients with concussion[47] Evidence suggests that a dose of 3 mg to 5 mg has utility in treating sleep disturbances and reducing depressive symptoms when compared with a placebo.[48] Optimization of sleep is critical in the recovery process to support mood and academic performance and should be monitored in pediatric patients with concussion.[47]

CONCLUSION

Concussion, a form of mild traumatic brain injury often seen in pediatric and adolescent populations, and by acute care surgeons, often in sports and recreational settings, involves the disruption of the homeostasis of neuronal cells of the brain in the absence of neuronal cell death. Despite scientific advances in the field, the diagnosis remains a clinical one, relying on clinician judgment through proper identification, diagnosis, and management. A visio-vestibular examination can help identify deficits and can both support diagnosis and help guide individualized multi-modal management plans. While most pediatric concussions resolve within 4 weeks, some patients may require specialized therapeutic rehabilitative interventions to achieve full resolution of concussion symptoms. Aerobic, vestibular, vision, behavioral, and sleep rehabilitation all play a critical role in pediatric concussion recovery and should be utilized when indicated. Focus on academic return and performance should be prioritized to minimize negative academic sequelae in pediatric patients. Effective management of the complex myriad of symptoms exhibited by pediatric and adolescent patients can help improve time to recovery and return patients to academic and athletic activity safely. The concussion evidence base continues to rapidly evolve, highlighting the need for clinicians to keep up-to-date on emerging translational clinical research and consensus guidelines for implementation to optimally diagnosis and manage pediatric concussion.

AUTHORSHIP

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DISCLOSURE

Conflict of Interest Statement: The authors have nothing to disclose. Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D601).

REFERENCES

1. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F, Seattle Sports Concussion Research Collaborative. Sports- and Recreation-Related Concussions in US Youth. *Pediatrics*. 2016;138(1):e20154635.
2. Patricios JS, Schneider KJ, Dvorak J, Ahmed OH, Blauwet C, Cantu RC, 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.
3. Clay MB, Glover KL, Lowe DT. Epidemiology of concussion in sport: a literature review. *J Chiropr Med*. 2013;12(4):230–251.
4. Kazl C, Torres A. Definition, classification, and epidemiology of concussion. *Semin Pediatr Neurol*. 2019;30:9–13.
5. Yard EE, Comstock RD. Compliance with return to play guidelines following concussion in US high school athletes, 2005–2008. *Brain Inj*. 2009; 23(11):888–898.
6. Jinguji TM, Krabak BJ, Satchell EK. Epidemiology of youth sports concussion. *Phys Med Rehabil Clin N Am*. 2011;22(4):565–575.
7. Signoretti S, Lazzarino G, Tavazzi B, Vagnozzi R. The pathophysiology of concussion. *PM R*. 2011;3(10 Suppl 2):S359–S368.
8. Cahill PJ, Refakis C, Storey E, Warner WC. Concussion in sports: what do orthopaedic surgeons need to know? *J Am Acad Orthop Surg*. 2016; 24(12):e193–e201.
9. Rose SC, Schaffer CE, Young JA, McNally KA, Fischer AN, Heyer GL. Utilization of conventional neuroimaging following youth concussion. *Brain Inj*. 2017;31(2):260–266.
10. Corwin DJ, Zonfrillo MR, Master CL, Arbogast KB, Grady MF, Robinson RL, et al. Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. *J Pediatr*. 2014;165(6):1207–1215.
11. Cuff S, Maki A, Feiss R, Young J, Shi J, Hautmann A, et al. Risk factors for prolonged recovery from concussion in young patients. *Br J Sports Med*. 2022;56(23):1345–1352.
12. Desai N, Wiebe DJ, Corwin DJ, Lockyer JE, Grady MF, Master CL. Factors affecting recovery trajectories in pediatric female concussion. *Clin J Sport Med*. 2019;29(5):361–367.
13. Chizuk HM, Cunningham A, Horn EC, Thapar RS, Willer BS, Leddy JJ, et al. Association of concussion history and prolonged recovery in youth. *Clin J Sport Med*. 2022;32(6):e573–e579.
14. Gioia GA, Schneider JC, Vaughan CG, Isquith PK. Which symptom assessments and approaches are uniquely appropriate for paediatric concussion? *Br J Sports Med*. 2009;43(Suppl 1):i13–i22.

15. Master CL, Scheiman M, Gallaway M, Goodman A, Robinson RL, Master SR, et al. Vision diagnoses are common after concussion in adolescents. *Clin Pediatr (Phila)*. 2016;55(3):260–267.
16. Vernau BT, Haider MN, Fleming A, Leddy JL, Willer BS, Storey EP, et al. Exercise-induced vision dysfunction early after sport-related concussion is associated with persistent postconcussive symptoms. *Clin J Sport Med*. 2023;33(4):388–394.
17. Storey EP, Master SR, Lockyer JE, Podolak OE, Grady MF, Master CL. Near point of convergence after concussion in children. *Optom Vis Sci*. 2017; 94(1):96–100.
18. Master CL, Bacal D, Grady MF, Hertle R, Shah AS, Strominger M, et al. Vision and concussion: symptoms, signs, evaluation, and treatment. *Pediatrics*. 2022;150(2):e2021056047.
19. Master CL, Master SR, Wiebe DJ, Storey EP, Lockyer JE, Podolak OE, et al. Vision and vestibular system dysfunction predicts prolonged concussion recovery in children. *Clin J Sport Med*. 2018;28(2):139–145.
20. Corwin DJ, Wiebe DJ, Zonfrillo MR, Grady MF, Robinson RL, Goodman AM, et al. Vestibular deficits following youth concussion. *J Pediatr*. 2015; 166(5):1221–1225.
21. Corrado C, Willer BS, McPherson JI, Storey EP, Sisto SA, Master CL, et al. Adolescents with more oculomotor and vestibular signs of sport-related concussion benefit from aerobic exercise: an exploratory analysis. *J Neurotrauma*. 2023;40(15–16):1718–1729.
22. Corwin DJ, McDonald CC, Arbogast KB, Mohammed FN, Grady MF, Master CL. Visio-vestibular deficits in healthy child and adolescent athletes. *Clin J Sport Med*. 2022;32(4):376–384.
23. Storey EP, Corwin DJ, McDonald CC, Arbogast KB, Metzger KB, Pfeiffer MR, et al. Assessment of saccades and gaze stability in the diagnosis of pediatric concussion. *Clin J Sport Med*. 2022;32(2):108–113.
24. Corwin DJ, Arbogast KB, Swann C, Haber R, Grady MF, Master CL. Reliability of the visio-vestibular examination for concussion among providers in a pediatric emergency department. *Am J Emerg Med*. 2020;38(9):1847–1853.
25. Davis GA, Patricios JS, Purcell LK, Anderson V, Gioia G, Giza CC, et al. Child SCOAT6. *Br J Sports Med*. 2023;57(11):672–688.
26. Corwin DJ, McDonald CC, Arbogast KB, Mohammed FN, Metzger KB, Pfeiffer MR, et al. Clinical and device-based metrics of gait and balance in diagnosing youth concussion. *Med Sci Sports Exerc*. 2020;52(3):542–548.
27. Macnow T, Curran T, Tolliday C, Martin K, McCarthy M, Ayturk D, et al. Effect of screen time on recovery from concussion: a randomized clinical trial. *JAMA Pediatr*. 2021;175(11):1124–1131.
28. Leddy JJ, Master CL, Mannix R, Wiebe DJ, Grady MF, Meehan WP, 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.
29. Wingerson MJ, Magliato SN, Smulligan KL, Wilson JC, Little CC, Howell DR. Predicting time to evaluation after pediatric concussion: factors affecting specialty concussion care. *Orthop J Sports Med*. 2023;11(8):23259671231186430.
30. Harmon KG, Drezner JA, Gammons M, Guskiewicz KM, Halstead M, Herring SA, et al. American Medical Society for Sports Medicine position statement: concussion in sport. *Br J Sports Med*. 2013;47(1):15–26.
31. Returning to School | HEADS UP | CDC Injury Center. Accessed January 29, 2024. https://www.cdc.gov/headsup/basics/return_to_school.html
32. Halstead ME, McAvoy K, Devore CD, Carl R, Lee M, Logan K, et al. Returning to learning following a concussion. *Pediatrics*. 2013;132(5): 948–957.
33. Cantu RC, Register-Mihalik JK. Considerations for return-to-play and retirement decisions after concussion. *PM R*. 2011;3(10 Suppl 2):S440–S444.
34. Eagle SR, Kontos AP, Pepping GJ, Johnson CD, Sinnott A, LaGoy A, et al. Increased risk of musculoskeletal injury following sport-related concussion: a perception-action coupling approach. *Sports Med*. 2020;50(1):15–23.
35. Leddy JJ, Haider MN, Ellis MJ, Mannix R, Darling SR, Freitas MS, et al. Early subthreshold aerobic exercise for sport-related concussion: a randomized clinical trial. *JAMA Pediatr*. 2019;173(4):319–325.
36. Haider MN, Bezherano I, Wertheimer A, Siddiqui AH, Horn EC, Willer BS, et al. Exercise for sport-related concussion and persistent postconcussive symptoms. *Sports Health*. 2021;13(2):154–160.
37. Chizuk HM, Willer BS, Cunningham A, Bezherano I, Storey E, Master C, et al. Adolescents with sport-related concussion who adhere to aerobic exercise prescriptions recover faster. *Med Sci Sports Exerc*. 2022;54(9):1410–1416.
38. Roby PR, Podolak OE, Grady M, Arbogast KB, Master CL. The effect of a home exercise program on visio-vestibular function in concussed pediatric patients. *Front Sports Act Living*. 2023;5:1064771.
39. Galeno E, Pullano E, Mourad F, Galeoto G, Frontani F. Effectiveness of vestibular rehabilitation after concussion: a systematic review of randomised controlled trial. *Healthcare (Basel)*. 2022;11(1):90.
40. Brown L, Camarinos J. The role of physical therapy in concussion rehabilitation. *Semin Pediatr Neurol*. 2019;30:68–78.
41. McAllister TW, Wall R. Neuropsychiatry of sport-related concussion. *Handb Clin Neurol*. 2018;158:153–162.
42. Xanthopoulos MS, Benton T, Lewis J, Case JA, Master CL. Mental health in the young athlete. *Curr Psychiatry Rep*. 2020;22(11):63.
43. Gornall A, Takagi M, Clarke C, Babl FE, Davis GA, Dunne K, et al. Behavioral and emotional difficulties after pediatric concussion. *J Neurotrauma*. 2020;37(1):163–169.
44. Macartney G, Woodfield M, Terekhov I, Vassilyadi M, Goulet K. Anxiety, depression, and symptom experience in concussed children and youth. *J Spec Pediatr Nurs*. 2021;26(1):e12310.
45. Podolak OE, Arbogast KB, Master CL, Sleet D, Grady MF. Pediatric sports-related concussion: an approach to care. *Am J Lifestyle Med*. 2021;16(4): 469–484.
46. Halstead ME. Pharmacologic therapies for pediatric concussions. *Sports Health*. 2016;8(1):50–52.
47. Barlow KM, Kirk V, Brooks B, Esser MJ, Yeates KO, Zemek R, et al. Efficacy of melatonin for sleep disturbance in children with persistent post-concussion symptoms: secondary analysis of a randomized controlled trial. *J Neurotrauma*. 2021;38(8):950–959.
48. Bramley H, Henson A, Lewis MM, Kong L, Stetter C, Silvis M. Sleep disturbance following concussion is a risk factor for a prolonged recovery. *Clin Pediatr (Phila)*. 2017;56(14):1280–1285.