Association of time to initial clinic visit with prolonged recovery in pediatric patients with concussion

Shawn R. Eagle, PhD, Anish Puligilla, Vanessa Fazio-Sumrok, PhD, Nathan Kegel, PhD, Michael W. Collins, PhD, and Anthony P. Kontos, PhD

Department of Orthopaedic Surgery, University of Pittsburgh; and UPMC Sports Medicine Concussion Program, Pittsburgh, Pennsylvania

OBJECTIVE No studies to date have investigated the role of early clinical care in time to recovery from concussion in a pediatric population. The purpose of this study was to investigate the role of clinic presentation timing (≤ 7 days [early] compared to 8–20 days [late] from injury) in concussion assessment performance and risk for prolonged recovery (> 30 days) in pediatric concussion.

METHODS This study is a retrospective cross-sectional study from a concussion clinic between April 2016 and January 2019, including 218 children and adolescents with diagnosed concussion, separated based on clinic presentation timing following injury: early (≤ 7 days) and late (8–20 days). Outcomes were recovery time, Postconcussion Symptom Scale (PCSS), Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), Vestibular/Ocular Motor Screen (VOMS), and demographics, medical history, and injury information. A general linear model and chi-square analyses were used to assess differences between early and late presentation, along with logistic regression, to predict prolonged recovery (> 30 days).

RESULTS Those with early presentation reported higher symptoms on VOMS subtests (79%–85%) compared to those with late presentation (61%–78%), with the exception of near-point of convergence distance and visual motion sensitivity (VMS). The strongest predictor of prolonged recovery was number of days to first clinic visit (OR 9.8). Positive VMS (OR 5.18), history of headache/migraine (OR 4.02), and PCSS score (OR 1.04) were also predictive of prolonged recovery.

CONCLUSIONS Despite patients in the early presentation group presenting with more positive VOMS scores, the early presentation group recovered sooner than patients in the late presentation group. Even after controlling for vestibular dysfunction, history of headache or migraine, and total symptom severity, days to first visit remained the most robust predictor of recovery > 30 days. These findings suggest that early, specialized medical care and intervention for children and adolescents with recent concussion is associated with normal recovery time. Clinicians should educate children and parents on the potential importance of early treatment to improve the odds of positive outcomes following concussion.

<https://thejns.org/doi/abs/10.3171/2020.2.PEDS2025>

KEYWORDS concussion; mild traumatic brain injury; early intervention; recovery; trauma

CONCUSSION, and its potential long-term health concerns and complications, remains a public health concern.¹ Often referred to as mild traumatic brain injury, concussion is a brain trauma defined as a complex pathophysiological process resulting from a transient disturbance of brain function.² Of particular concern is the effect concussions may have on the developing pediatric

brain.¹ The true incidence of pediatric concussion is unknown, as it relies entirely on patient self-report, but it is estimated that 16% of 10-year-olds have required medical attention for a head injury.³ Further, there are approximately 700,000 emergency department visits for pediatric traumatic brain injury each year in the US, with up to 1.8 million sport-related concussions in children and adoles-

ABBREVIATIONS ADHD = attention-deficit hyperactivity disorder; ImPACT = Immediate Post-Concussion Assessment and Cognitive Testing; LD = learning disorder; NPC = near-point of convergence; OR = odds ratio; PCSS = Postconcussion Symptom Scale; VMS = visual motion sensitivity; VOMS = Vestibular/Ocular Motor Screen; VOR = vestibular-ocular reflex.

SUBMITTED January 7, 2020. **ACCEPTED** February 24, 2020.

INCLUDE WHEN CITING Published online April 24, 2020; DOI: 10.3171/2020.2.PEDS2025.

cents.^{3,4} While it is known that children and adolescents typically recover from concussion within 1 month,⁵ little evidence is available regarding factors that may prolong recovery from concussion in this population.

Zemek et al.⁶ reported that older children have an increased risk of prolonged concussion symptoms with loss of consciousness, headache, nausea, and vomiting. The authors also reported that dizziness and premorbid conditions (i.e., previous head injury, learning disability, or behavioral problems) may have increased risk for prolonged symptoms.⁶ Grool et al.⁷ reported that any activity within 7 days of acute concussion (compared to no activity at all) was associated with reduced risk of persistent concussion-related symptoms 1 month postinjury in a pediatric sample. While this study provided useful information in regards to the efficacy of general exercise following pediatric concussion, the benefits were relative to complete rest.⁷ Consensus guidelines are clear that extended periods of rest (> 48 hours) and/or isolation are not recommended and may be a risk factor for prolonged recovery.^{2,8}

A large body of evidence exists examining additional risk factors for prolonged recovery following concussion, including female sex,⁹ initial symptom severity,¹⁰ history of motion sickness,¹¹ history of psychiatric disorder,¹¹ history of migraine,¹² continuing to play following injury,¹³ or previous concussion.⁹ However, an often-ignored variable is time between the injury and visiting a clinic for medical care. The timing for initiation of exercise, as well as a prescription of appropriate exercise, is critical following concussion. Research suggests that prolonged rest may increase the risk of longer overall recovery,¹⁴ but exercise that is too strenuous has been shown to complicate outcomes as well.¹⁵ Furthermore, expert consensus advocates for graded, subsymptom-threshold aerobic exercise in conjunction with specialized targeted therapies as needed (e.g., vestibular, ocular, and/or cervical).² Thus, obtaining appropriate medical care and guidance earlier in concussion recovery may expedite recovery from the injury. However, no studies to date have investigated the role of early clinical care in time to recovery from concussion in a pediatric population. The purpose of this study was to investigate the role of specialty-clinic presentation timing (≤ 7 days [early] compared to 8–20 days [late] from injury) in concussion assessment performance and risk for prolonged recovery (> 30 days) in pediatric concussion.

Methods

Design and Participants

The present study was a cross-sectional chart review of clinical and demographic data from patients who presented to a concussion specialty clinic between April 2016 and January 2019, were eligible, and consented to participate in ongoing research. Patients were eligible to participate if they were between 12 and 17 years of age with a diagnosed, symptomatic concussion per current consensus guidelines ($n = 232$).⁸ Patients with moderate to severe traumatic brain injury, neurological disorder, or preexisting vestibular disorder were excluded from analysis. Fourteen patients were excluded for incomplete recovery data, leaving a total sample size of 218.

Measures

Demographics and Medical History

Participants self-reported demographics (e.g., age, sex, sport), relevant medical history (e.g., previous diagnosis of ocular impairment, attention-deficit hyperactivity disorder [ADHD], learning disorder [LD], headaches, migraines, family history of migraines, motion sickness, personal psychiatric history, and concussion history), and information specific to the injury (e.g., date and mechanism of injury and initial signs and symptoms, such as loss of consciousness, posttraumatic amnesia, initial confusion or disorientation) in a standardized clinical interview.

Concussion Symptoms

Participants completed the Postconcussion Symptom Scale (PCSS), which is a self-report survey measuring concussion symptom severity.¹⁶ The PCSS has 22 items comprising physical, cognitive, affective, and sleep-related concussion symptoms, rated on a 7-point Likert scale from 0 (none) to 6 (severe). The maximum score for the PCSS is 132. The PCSS takes less than 3 minutes to complete.

Neurocognition

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) computerized test battery was utilized to measure neurocognition.¹⁷ The ImPACT battery contains 6 cognitive subtests that comprise 4 composite scores used for analysis. Raw composite scores include verbal memory, visual memory, visual motor processing speed, and reaction time (seconds). With the exception of reaction time, higher scores are indicative of better performance. The ImPACT battery requires 20–30 minutes to complete.

Vestibular and Ocular Function

The Vestibular/Ocular Motor Screen (VOMS) was utilized to measure vestibular and ocular symptoms/impairment.¹⁸ Prior to VOMS, participants are asked to rate their current level of headache, dizziness, nausea, and foggy on a 0–10 scale, in which 10 indicates maximum severity. Following each of the 7 VOMS subtests, symptoms are re-recorded to determine the degree of symptom provocation. The subtests include smooth pursuits, horizontal and vertical saccades, near-point of convergence (NPC), horizontal and vertical vestibular-ocular reflex (VOR), and visual motion sensitivity (VMS). Symptoms are totaled for each subtest, and distance is recorded for NPC in centimeters. For analysis, a binary (yes/no) variable is recorded based on clinical cutoffs reported in previous research (score > 2 on an individual subtest or NPC distance > 5 cm). VOMS takes approximately 5 minutes to complete.

Recovery Time

Recovery was operationally defined by current consensus guidelines; clearance for full activity was indicated following a return to baseline level of symptoms; cognitive, ocular, and vestibular performance at rest; with no increase in symptoms following exertion. Recovery time was recorded as number of days from the date of injury to the date of clearance for full activity. Participants were

TABLE 1. Differences between early (n = 145) and late (n = 82) presentation in demographics, neurocognition, and concussion symptoms

Variable	Early	95% CI	Late	95% CI	p Value
Age	14.7 ± 0.1	14.5–15.0	14.9 ± 0.2	14.5–15.3	0.47
Female	43 (30%)	NA	49 (60%)	NA	<0.001*
History of motion sickness	38 (26%)	NA	17 (21%)	NA	0.445
History of anxiety or depression	19 (13%)	NA	9 (11%)	NA	0.663
History of ADHD or LD	9 (6%)	NA	5 (6%)	NA	0.966
History of headache or migraine	52 (36%)	NA	30 (37%)	NA	0.890
Days to first visit	3.9 ± 0.2	3.5–4.4	11.8 ± 0.3	11.2–12.3	<0.001*
Days to recovery	37.3 ± 0.2	36.9–37.7	45.1 ± 0.3	44.6–45.7	<0.001*
Days from first visit to recovery	34.1 ± 2.8	28.7–39.6	32.0 ± 3.8	24.4–39.6	0.667
Verbal memory	78.3 ± 1.3	75.7–80.8	77.2 ± 1.8	73.7–80.7	0.63
Visual memory	67.0 ± 1.3	64.4–69.5	65.4 ± 1.8	61.8–68.9	0.49
Visual motor speed	33.1 ± 0.7	31.8–34.4	31.1 ± 0.9	29.2–33.0	0.10
Reaction time	0.7 ± 0.01	0.68–0.74	0.7 ± 0.02	0.70–0.78	0.27
PCSS score	30.4 ± 1.6	27.2–33.6	25.0 ± 2.2	20.5–33.6	0.06

NA = not available.

Data given as value (percentage) or mean ± SE.

* Statistically significant (p < 0.05).

then separated into ≤ 30-day and > 30-day cohorts for analysis, based on the cutoff for typical recovery in this population.⁵

Procedures

Participants and their parents were informed about study procedures before providing informed consent with child assent prior to study participation. Eligible participants were enrolled at their first visit to the clinic with concussion. Participants completed demographics and injury information, the PCSS, ImPACT battery, and VOMS in order. All assessments were administered by trained clinicians as part of a standard clinical examination. Participants were followed at regular clinical intervals (approximately 5 to 7 days apart) to assess recovery status. This study was approved by the university institutional review board for human subjects research.

Statistical Analysis

Participants were categorized into patients who presented to the clinic within 7 days of the injury (early presentation) and patients who presented 8–20 days from the injury (late presentation). A general linear model was used to compare the groups in demographics and concussion assessment performance at the presenting visit. Covariates that are known to influence concussion outcomes were applied to the model, including sex and history of motion sickness, personal psychiatric disorder, ADHD or LD, and headache or migraine history. Type of injury (sport-related concussion [n = 175] or nonsport-related concussion [n = 43]) and number of days from first visit to clearance were also included as covariates. Chi-square analyses were run for between-group differences in proportion of early and late presentations with clinically significant (> 2 symptoms reported) VOMS subtest symptom scores. Adjusted odds ratios (ORs) were derived from a multivariate backward

stepwise logistic regression model, in which the outcome was normal (≤ 30 days) or prolonged (> 30 days) recovery. All study outcomes, including demographics, medical history risk factors, and concussion assessment performance, were included as predictors in the original model. Individual predictors were systematically removed from the model if they did not significantly contribute to model performance (p < 0.05). Post hoc model diagnostics were conducted to evaluate the model for violated assumptions. To evaluate collinearity, variable inflation factors (cutoff for inclusion was individual variable inflation factors < 4) and partial correlations (cutoff for inclusion was r < 0.8) were conducted. Statistical significance was set a priori at p < 0.05. Analyses were conducted using Stata software (version 15.1, StataCorp).

Results

There were no differences in age, symptoms, or neurocognitive performance at first visit between early and late presentations (Table 1). The mean number of days to first visit was significantly longer for late presentation (11.8 days) compared to early presentation (3.9 days). The number of days to recovery was also significantly longer for late presentations (45.1 days) relative to early presentations (37.3 days). Late presentations had a higher proportion of females (49/82, 60%) than early presentations (43/145, 30%). There were no significant differences between early and late presentations in history of motion sickness, anxiety/depression, ADHD/LD, or headache/migraine (Table 1). Early presentations had a higher proportion who reported clinically significant symptom scores for each VOMS subtest, with the exception of NPC distance and VMS, compared to late presentations (Table 2).

The logistic regression model identified number of days to first visit (OR 9.80), VMS above clinical cutoff (OR 5.18), history of headache and/or migraine (OR 4.02),

TABLE 2. Number and proportion of early and late presentations with VOMS subtest symptom scores over clinical cutoffs

VOMS Subtest	Early (%)	Late (%)	p Value
Smooth pursuits	114 (79)	50 (61)	0.004*
Horizontal saccades	117 (81)	53 (65)	0.007*
Vertical saccades	116 (80)	54 (66)	0.018*
NPC	114 (79)	53 (65)	0.022*
NPC distance	45 (31)	25 (31)	0.898
Horizontal VOR	120 (83)	59 (72)	0.043*
Vertical VOR	119 (82)	58 (71)	0.037*
VMS	123 (85)	64 (78)	0.159

* Statistically significant ($p < 0.05$).

and PCSS score (OR 1.04) as significant predictors of prolonged recovery (> 30 days; Table 3). Overall, the model significantly predicted prolonged recovery (Nagelkerke $R^2 = 0.26$, $p < 0.001$) with a likelihood ratio of 43.1.

Discussion

The purpose of this study was to evaluate differences between pediatric patients who presented to a concussion clinic within 7 days of injury (early presentation) and pediatric patients who presented within 8–20 days (late presentation), as well as to evaluate the potential relationship between early and late presentation and days to recovery. The results of this study showed that patients in the early presentation group were cleared to return to full activity approximately 8 days earlier than those with late presentation, despite no significant differences in age, neurocognitive performance, and concussion-specific symptoms (Table 1). Moreover, early presentation had a larger proportion of participants with clinically significant symptomatology in each of the VOMS subtests, with the exception of NPC distance and VMS (Table 2). Additionally, the number of days to first visit was the most significant predictor of prolonged recovery (> 30 days) in this pediatric population, as late presentation had 880% increased odds of recovery taking longer than 30 days relative to early presentation (Table 3). The results of this study demonstrate an association between presenting to a concussion clinic within 7 days of injury and the likelihood of quicker recovery, compared to those who present to clinic later (8–20 days).

The results of this study support the idea that earlier clinical care is associated with faster recovery following

concussion in a pediatric population. Both early and late presentation groups received treatment within an active rehabilitation model that is targeted to their individual response to the injury, regardless of when the individual presented.¹⁹ Therefore, initiating subsymptom exercise, behavioral management strategies, and prescribed therapies for specific complications (e.g., vestibular, ocular, etc.) sooner results in improved outcomes. This is evidenced by the lack of differences between early and late presentation in number of days from the first visit to recovery (Table 1). This result indicates that early, specialized concussion care in the acute and subacute stages of concussion recovery is critical to shortening overall recovery. Specifically, it is not possible to account for the activities late presentation participants may have been engaging in prior to their first clinical visit. If late presentation participants were engaged in less-informed treatment strategies, such as “cocoon therapy,”²⁰ excessive physical exercise,¹⁵ or continuing to play after the injury,¹³ this could have prolonged recovery time. Additionally, late presentation participants could have adopted a “wait and see” approach, choosing to wait for symptoms to improve spontaneously, thus delaying initiation of exercise and targeted treatments.

On average, late presentation patients presented approximately 8 days later than those in the early presentation group (Table 1). There were no differences in age, neurocognitive performance, or concussion symptom severity between groups. Interestingly, a significantly larger proportion of early presentation patients reported clinically significant VOMS scores compared to late presentation patients (Table 2). The late presentation group also comprised more females than the early presentation group (Table 1), which is clinically relevant because female sex has previously been associated with prolonged recovery from concussion.²¹ While this difference between groups may have itself been related to increased recovery time, sex was removed from the backward stepwise logistic regression model for limited association with prolonged recovery when controlling for the other predictors (Table 3). Vestibular-ocular impairments and/or symptoms may have led to early presentation patients seeking clinical care sooner or may be a function of the acute nature of the injury when they were seen. However, even with a larger proportion with vestibular-ocular impairments, a risk factor for prolonged recovery,²² there was no difference between groups in number of days between first visit and recovery (Table 1). Thus, if adequate treatment is eventually sought, total recovery time is associated with an earlier intervention in this population.

Logistic regression analysis revealed number of days to first visit as the strongest predictor (OR 9.8) of recovery > 30 days in this population (Table 3). This result occurred after considering VMS symptoms, history of headache/migraine, and concussion symptom severity, which were also significant predictors of prolonged recovery (Table 3). This is a clinically meaningful result because number of days to first visit was a more robust predictor than the additional predictors included in the model, which are well-established risk factors for prolonged recovery,^{2,10,22} such as sex, type of injury, and history of motion sickness, previous concussion, and psychological disorder, among oth-

TABLE 3. Adjusted ORs for prolonged recovery using preinjury risk factors and first-visit assessments as predictors

Risk Factor	OR	95% CI	p Value*
Days to first visit	9.80	3.32–29.00	$<0.001^*$
VMS	5.18	1.52–17.60	0.002*
History of headache/migraine	4.02	1.49–10.87	0.008*
PCSS score	1.04	1.02–1.07	0.002*

* All values were statistically significant ($p < 0.05$).

ers.^{9,22,23} The results of this study highlight the importance of increasing awareness about the safety and efficacy of early concussion treatment. Early intervention may help return recently concussed patients to normal activities sooner, decrease the likelihood of chronic symptoms and/or impairment, and decrease the risk of mood-related difficulties due to extended time away from sport or activities.

This study adds to the literature by emphasizing the importance of early clinical care to quicker recovery in concussion, and providing more evidence to support current consensus guidelines that advocate for a short period of relative rest followed by graded, subsymptom activity.⁸ Only one prior study has investigated the role of early clinical care (< 1 week vs 2–3 weeks) in concussion recovery.²⁴ Kontos et al.²⁴ reported a logistic regression model with clinical presentation at 2–3 weeks (OR 6.1) and positive history of migraine (OR 3.1) as the only significant predictors to prolonged recovery from sport-related concussion in a sample of 12- to 22-year-olds. The present study aimed to examine the relationship between early clinical care in a pediatric-only population because younger patients typically take longer to recover than adults.⁵ Furthermore, the present study increases generalizability within this population by incorporating nonsport-related concussions, which is important given that more than 50% of concussed patients 0–18 years of age obtained their injury participating in organized sports.⁴ Finally, the present study utilized an enhanced predictor model, including all predictors from Kontos et al.²⁴ with the addition of history of motion sickness,²³ ocular impairment,²⁵ family history of migraine or psychiatric disorders,^{12,26} and suspected history of migraine by the clinician, based on the medical history interview (but not previously diagnosed).

This study has some limitations. The association between time to first visit and prolonged recovery may also be mitigated by other factors, such as access to healthcare, availability to attend multiple appointments (e.g., initial visit through recovery), failure to return to the clinic for official clearance, socioeconomic status, education, insurance status, differences in sport culture, and individual motivation to return to sport, which were unavailable in the present study. Future prospective studies should also consider these potential factors on prolonged recovery from concussion. Specific therapeutic prescriptions were not available for this analysis, so it is unknown which interventions (e.g., behavioral modifications, medications, therapies, etc.) were necessary for the participants. Adherence to the prescribed therapies was also not collected, so it is unknown if there were between-group differences in completing prescribed exercises. Participants may have inadvertently affected recovery by their actions prior to presenting to the concussion clinic, such as continuing to play after injury, avoiding school, dysregulation, or isolating themselves to a dark room. This possibility is further complicated by a propensity for athletes to fail to recognize and/or report concussion, which prolongs recovery.²⁷ Generalizability may also be limited to very young children (under 10 years of age) as well, given developmental differences in cognitive function and ability to report symptoms.²⁸ However, investigating the importance of

early interventions following concussion in children and adolescents is still a relevant public health concern, as up to 1.8 million concussions from sport alone occur annually in this age group.⁴ Each patient's individual sport was also unavailable for the present study; future studies should examine if athletes from certain sports report earlier for evaluation when a concussion is suspected, in comparison to others.

Conclusions

The purpose of this study was to investigate the role of clinical care timing following concussion on recovery time in pediatric patients. The results of this study suggest an association between presenting to the clinic 2–3 weeks after sustaining a concussion and increasing the odds of prolonged recovery 9.8 times, compared to those who presented in a week or less. This finding, relative to other signs, symptoms, and impairments of concussion, suggests that advocating for early, active intervention in concussed children and adolescents may be important. The importance of early intervention is also supported by the lack of differences between groups in days from first visit to clinical recovery, indicating that days before first visit played a critical role in long-term recovery. Future work should investigate the role of timing in efficacy of different postconcussion therapies (e.g., vestibular, exertion, vision), the role of early re-engagement in school and physical activity, as well as comparison of the effect of early versus late interventions on different mechanisms of injury (e.g., sport-related vs nonsport-related). Future work should also investigate if treatment pathways should be modified based upon timing of first clinical visit.

References

- Chrisman SPD. Exercise and recovery time for youth with concussions. *JAMA Pediatr.* 2019;173(4):315–316.
- Harmon KG, Clugston JR, Dec K, et al. American Medical Society for Sports Medicine position statement on concussion in sport. *Br J Sports Med.* 2019;53(4):213–225.
- Faul M, Xu L, Wald MM, Coronado VG: *Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths 2002–2006*. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010. https://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf. Accessed March 6, 2020.
- Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F. Sports- and recreation-related concussions in US youth. *Pediatrics.* 2016;138(1):e20154635.
- Zemek R, Barrowman N, Freedman SB, et al. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. *JAMA.* 2016;315(10):1014–1025.
- Zemek RL, Farion KJ, Sampson M, McGahern C. Prognosticators of persistent symptoms following pediatric concussion: a systematic review. *JAMA Pediatr.* 2013;167(3):259–265.
- Grool AM, Aglipay M, Momoli F, et al. Association between early participation in physical activity following acute concussion and persistent postconcussive symptoms in children and adolescents. *JAMA.* 2016;316(23):2504–2514.
- McCroory P, Meeuwisse W, Dvořák J, et al. Consensus statement on concussion in sport—the 5th international confer-

- ence on concussion in sport held in Berlin, October 2016. *Br J Sports Med.* 2017;51(11):838–847.
9. Scopaz KA, Hatzenbuehler JR. Risk modifiers for concussion and prolonged recovery. *Sports Health.* 2013;5(6):537–541.
  10. Meehan WP III, Mannix RC, Straccolini A, et al. Symptom severity predicts prolonged recovery after sport-related concussion, but age and amnesia do not. *J Pediatr.* 2013;163(3):721–725.
  11. Corwin DJ, Zonfrillo MR, Master CL, et al. Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. *J Pediatr.* 2014;165(6):1207–1215.
  12. Sufrinko A, McAllister-Deitrick J, Elbin RJ, et al. Family history of migraine associated with posttraumatic migraine symptoms following sport-related concussion. *J Head Trauma Rehabil.* 2018;33(1):7–14.
  13. Elbin R, Sufrinko A, Schatz P, et al. Removal from play after concussion and recovery time. *Pediatrics.* 2016;138(3):e20160910.
  14. Thomas DG, Apps JN, Hoffmann RG, et al. Benefits of strict rest after acute concussion: a randomized controlled trial. *Pediatrics.* 2015;135(2):213–223.
  15. Majerske CW, Mihalik JP, Ren D, et al. Concussion in sports: postconcussive activity levels, symptoms, and neurocognitive performance. *J Athl Train.* 2008;43(3):265–274.
  16. Kontos AP, Elbin RJ, Schatz P, et al. A revised factor structure for the post-concussion symptom scale: baseline and postconcussion factors. *Am J Sports Med.* 2012;40(10):2375–2384.
  17. Schatz P, Pardini JE, Lovell MR, et al. Sensitivity and specificity of the ImPACT Test Battery for concussion in athletes. *Arch Clin Neuropsychol.* 2006;21(1):91–99.
  18. Mucha A, Collins MW, Elbin RJ, et al. A brief Vestibular/Ocular Motor Screening (VOMS) assessment to evaluate concussions: preliminary findings. *Am J Sports Med.* 2014;42(10):2479–2486.
  19. Kontos AP, Collins MW, Holland CL, et al. Preliminary evidence for improvement in symptoms, cognitive, vestibular, and oculomotor outcomes following targeted intervention with chronic mTBI patients. *Mil Med.* 2018;183(suppl_1):333–338.
  20. Giza CC, Choe MC, Barlow KM. Determining if rest is best after concussion. *JAMA Neurol.* 2018;75(4):399–400.
  21. 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.
  22. Master CL, Master SR, Wiebe DJ, et al. Vision and vestibular system dysfunction predicts prolonged concussion recovery in children. *Clin J Sport Med.* 2018;28(2):139–145.
  23. Sufrinko AM, Kegel NE, Mucha A, et al. History of high motion sickness susceptibility predicts vestibular dysfunction following sport/recreation-related concussion. *Clin J Sport Med.* 2019;29(4):318–323.
  24. Kontos AP, Jorgensen-Wagers K, Trbovich AM, et al. Association of time since injury to the first clinic visit with recovery following concussion [published online January 6, 2020]. *JAMA Neurol.* doi:10.1001/jamaneurol.2019.4552
  25. Anzalone AJ, Blueitt D, Case T, et al. A positive vestibular/ocular motor screening (VOMS) is associated with increased recovery time after sports-related concussion in youth and adolescent athletes. *Am J Sports Med.* 2017;45(2):474–479.
  26. Sandel N, Reynolds E, Cohen PE, et al. Anxiety and mood clinical profile following sport-related concussion: from risk factors to treatment. *Sport Exerc Perform Psychol.* 2017;6(3):304–323.
  27. Asken BM, McCrea MA, Clugston JR, et al. “Playing through it”: delayed reporting and removal from athletic activity after concussion predicts prolonged recovery. *J Athl Train.* 2016;51(4):329–335.
  28. Reynolds E, Fazio VC, Sandel N, et al. Cognitive development and the immediate postconcussion assessment and cognitive testing: a case for separate norms in preadolescents. *Appl Neuropsychol Child.* 2016;5(4):283–293.

Disclosures

M.W.C. is a co-founder and shareholder of ImPACT applications. M.W.C. and A.P.K. receive royalties from American Psychological Association Books. A.P.K. has received support of non-study-related clinical or research effort from the National Football League.

Author Contributions

Conception and design: Eagle. Acquisition of data: Fazio-Sumrok, Kegel, Collins, Kontos. Analysis and interpretation of data: Eagle, Puligilla, Fazio-Sumrok, Kontos. Drafting the article: Eagle, Puligilla, Kegel, Collins. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Eagle. Statistical analysis: Eagle. Study supervision: Kontos.

Correspondence

Shawn R. Eagle: University of Pittsburgh School of Medicine, Pittsburgh, PA. seagle@pitt.edu.