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Effect of Cognitive and Physical Rest on Persistent Postconcussive Symptoms following a Pediatric Head Injury

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Objective To evaluate the effect of cognitive and physical rest on persistent postconcussive symptoms in a pediatric population.

Study design A prospective cohort study of 5- to 18-year-olds diagnosed with an acute concussion in a tertiary care pediatric emergency department was conducted from December 2016 to May 2019. Participants (n = 119) were followed over 1 month to track days off from school and sports and the development of persistent postconcussive symptoms (residual concussion symptoms beyond 1 month). Participants were dichotomized into minimal (≤2) and moderate (>2) rest, based on days off from school and sports after a concussion. Univariate and multivariable logistic regression analyses were completed to examine associations with persistent postconcussive symptoms.

Results Of the participants in our study, 24% had persistent postconcussive symptoms. Adolescent age, history of prolonged concussion recovery, and headache at presentation were associated with higher odds of persistent postconcussive symptoms in univariate analyses. In a multivariable logistic regression model, only adolescent age was associated with increased odds of persistent postconcussive symptoms. Compared with the minimal cognitive rest group, moderate cognitive rest did not decrease the odds of persistent postconcussive symptoms (aOR, 1.15; 95% CI, 0.44-2.99). Compared with the minimal physical rest group, moderate physical rest also did not decrease the odds of persistent postconcussive symptoms (aOR, 3.17; 95% CI, 0.35-28.78).

Conclusions Emerging evidence supports early return to light activity for recovery of acute pediatric concussion. Our study adds to this management approach as we did not find that rest from school and sports resulted in a decreased odds of persistent postconcussive symptoms. *(J Pediatr 2020;227:184-90)*.

Children in the US sustain as many as 1 800 000 closed head injuries annually, accounting for approximately 500 000 emergency department (ED) visits and 800 000 outpatient visits each year.[1-3] Although many youth recover within 2 weeks, a substantial minority experience symptoms for 4 weeks or more.[4] Defined here as concussion-related symptoms persisting beyond 1 month, persistent postconcussive symptoms include physical and cognitive dysfunction, sleep disturbances, and behavioral changes that can lead to missed days of school and work, impaired academic performance, mood changes, and decreased quality of life.[5-7] Known risk factors for pediatric persistent postconcussive symptoms include adolescent age, female sex, history of persistent postconcussive symptoms, history of migraines, difficulty answering questions, headache, sensitivity to noise, and fatigue at initial ED presentation.[4]

Concussions have historically been managed conservatively with a treatment model based in cognitive and physical rest.[8-12] These rest-based treatments include limitations on academic activity, including mental tasks requiring memory, concentration, and reasoning, as well as abstention from physical activity.[8,11-13] Some studies have shown that cognitive rest does not improve recovery, but these studies were limited owing to a short follow-up time period (10 days) and their inclusion of only young adults.[14,15]

Other studies have demonstrated that rest is unhelpful to recovery, and that early resumption of physical activity may be beneficial.[12,14-25] The International Concussion in Sport Group consensus statement notes that after a brief period of rest (24-48 hours), the group recommends progressive cognitive and physical activity.[26] Additionally, the latest guidelines from the American Academy of Pediatrics support the reduction—not complete elimination—of physical and cognitive activity.[16]

Given conflicting opinions about rest and recovery, and the need for longer follow-up with specifically pediatric patients, the aim of this study was to examine further the effect of cognitive and physical rest on persistent postconcussive symptoms in a pediatric sample 1 month after injury. We hypothesized

ED	Emergency department
PCSI	Postconcussion Symptom Inventory

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that both cognitive and physical rest would not decrease the odds of persistent postconcussive symptoms.

Methods

Patients diagnosed with an acute concussion were prospectively recruited from our tertiary care pediatric ED or satellite community ED from December 2016 to May 2019. Research assistants or project investigators were typically available to approach patients from 8:00 a.m. to 11:00 p.m. daily.

Participants were considered eligible if they were English or Spanish speaking, greater than 5 years and less than 19 years old, and had an acute concussion within 48 hours of presentation. A concussion was defined as closed head trauma with associated signs and symptoms of a concussion, such as answering questions slowly, headache, nausea or vomiting, blurry vision, and/or difficulty concentrating.[27] Patients were ineligible if they had a major psychiatric diagnosis, such as schizophrenia or bipolar disorder; a history of cognitive delay; intracranial pathology (such as a ventriculoperitoneal shunt) or prior neurosurgical procedure; positive findings of traumatic brain injury on a computed tomography scan of head (if obtained); or a Glasgow Coma Scale score of 13 or less at the time of diagnosis. This project was approved by the hospital's institutional review board.

To investigate the relationship between rest and persistent postconcussive symptoms, participants were categorized as minimal or moderate rest after concussion. Participants who took 2 or fewer days off from school were classified as minimal cognitive rest, and participants who took more than 2 days off from school were classified as moderate cognitive rest. Similarly, we dichotomized participants into minimal and moderate physical rest. Participants who took 2 days or fewer off from sports activities were classified as minimal physical rest, and participants who took 2 days or more off from sports activities were classified as moderate physical rest. We chose to dichotomize these results as 2 days or fewer and 2 or more days off from school, as the most recent consensus guidelines on concussion management recommend progressive return to cognitive and athletic activities after a brief 1- to 2-day rest period.[26]

All enrolled participants completed the validated Postconcussion Symptom Inventory (PCSI) to assess their current symptom burden.[28] The PCSI is an age-based 5- to 20-question survey that asks participants to rate their preinjury and current concussion symptoms on an age-appropriate Guttman scale (**Figure 1**; available at www.jpeds.com). Of note, although the original 13-item version was completed by 5- to 7-year-old participants, only the 5-item version was analyzed for this study. For all ages, preinjury adjusted scores were calculated (ie, postinjury minus preinjury rating) to capture increases in symptoms associated with the concussion. Participants were then classified as either within or exceeding the 80% Reliable Change Index-based CIs published in the latest version of the PCSI,[29] which are based on test-retest data of preinjury ratings and indicate whether there is a significant difference between preinjury symptoms and current symptoms. For the 5- to 7-year-olds, for whom Reliable Change Index cutoffs were not published, the cutoffs were calculated using the normative data sample from the published PCSI-2.[29] These classifications were used to determine the primary outcome: no persistent postconcussive symptoms (within 80% CI) or persistent postconcussive symptoms (exceeding the 80% CI and indicating presence of significantly higher symptoms than at preinjury).

Participants also completed a questionnaire assessing their risk factors for persistent postconcussive symptoms, based on the study by Zemek et al, which derived and validated a pediatric concussion risk score in more than 3000 pediatric patients.[4]

Participants received verbal and printed discharge instructions on their acute concussion from their individual ED provider. After the initial data collection and discharge from the ED, research coordinators contacted participants via phone 7-10 days after their injury to determine how many days participants refrained from school and sports activities. For students that were not in school (because of age, school breaks, or vacation), we asked how many days they took off from their usual non-sports-related activities. Research coordinators recontacted participants 28-32 days after discharge via phone or email to complete the PCSI. If research assistants were unable to reach patients for follow-up via phone, at least 3 additional follow-up phone calls or emails were made over the course of 2 weeks to maximize study participant retention.

Statistical Analyses

Descriptive statistics were collected, and χ^2 analyses were performed comparing participants who took moderate vs minimal cognitive rest, and comparing enrolled participants with those lost to follow-up.

A series of univariable logistic regression analyses were performed to assess individual variable associations with persistent postconcussive symptoms. Included in the analyses were known risk factors for persistent postconcussive symptoms,[4] along with cognitive and physical rest. These risk factors included age, sex, mechanism of injury, history of concussion with prolonged recovery, history of physician-diagnosed migraines, high scores on the Balance Error Scoring System, and symptoms at initial ED visit, including headache, fatigue, and sensitivity to noise.[4,30] A final multivariable logistic regression model was built to assess variable associations with persistent postconcussive symptoms. Independent variables related to our primary outcome along with those variables that had a level of significance less than .10 in the univariable logistic regression analyses were included in the final model.

Sample Size

We estimated a 30% prevalence of persistent postconcussive symptoms based on a recent publication of risk factors for persistent postconcussive symptoms in more than 3000 pediatric patients in Canada.[4] Peduzzi et al recommended 10 times the number of predictors, *k*, taking into account the proportion, *p*, of successes, $n = 10k/p$.[31] With 4 covariates, the minimum number of cases would be 133. Assuming a 25% loss to follow-up, we aimed to recruit 180 patients in our study.

Results

A total of 1056 patients were screened for eligibility by the research staff; of these, 420 were deemed eligible (**Figure 2**). A total of 237 potential participants were not enrolled for reasons such as parent and patient refusal, rapid discharge from the ED before research staff could approach the patients, and unavailability of research staff to enroll. A total of 183 patients were initially enrolled in our study. Nine patients were removed from the analysis owing to errors in their follow-up PCSI scores and 55 patients were lost to follow-up, leaving 119 patients in our study sample.

Baseline patient demographics, injury mechanism, and initial ED symptoms and signs of the 119 patients enrolled in the study are shown in **Table I**. Participants were divided between those who took moderate cognitive rest (>2 days off from school), those who took minimal cognitive rest (≤2 days off from school), and those lost to follow-up. The moderate cognitive rest group was slightly older than the minimal cognitive rest cohort (mean age, 11.6 years vs 10.4 years; $P = .07$), slightly less likely to have had a concussion as a result of a fall (37.8% vs 52.7%; $P = .04$), and slightly more likely to have had a headache as a symptom after injury (77.8% vs 60.8%; $P = .06$). Both groups had a similar concussion symptom score (median of 9.0 vs 8.0 for moderate vs minimal rest, respectively; $P = .31$). Additionally, participants in the moderate cognitive rest group took similar days off from sports activities (mean, 8.3 days vs 7.3 days; $P = .30$) compared with the minimal cognitive rest group.

We also compared those participants lost to follow-up with the 119 study participants. Participants lost to follow-up were more likely to have been male, to have had a concussion as a result of a fall, and to have a physician-diagnosed history of migraines (**Table II**; available at www.jpeds.com).

Overall, 24.4% of participants in our study had persistent postconcussive symptoms, 20.3% of the minimal cognitive rest group and 31.1% of the moderate cognitive rest group. In the univariate logistic regression analyses (**Table III**), age group 13-18 years old, prior history of prolonged concussion, and headache at presentation were associated with higher odds of persistent postconcussive symptoms. We included independent variables related to our primary outcome and significant covariates in a final multivariable logistic regression model and age group 13-18 years old was the only variable that remained significantly associated with odds of persistent postconcussive symptoms (**Table IV**). Teenagers had significantly higher odds of persistent postconcussive symptoms compared with the reference group of 5- to 7-year-olds (aOR, 5.57; 95% CI, 1.08-28.69). When 8-12 years old was used as the reference group, 13-18 year-olds had a 2.35 times higher adjusted odds of persistent postconcussive symptoms (95% CI, 0.86-6.45; $P = .10$). No association was observed between cognitive and physical rest and the odds of persistent postconcussive symptoms in either the univariate or multivariable logistic regression analyses. Compared with the minimal cognitive rest group, moderate cognitive rest had an unadjusted OR of persistent postconcussive

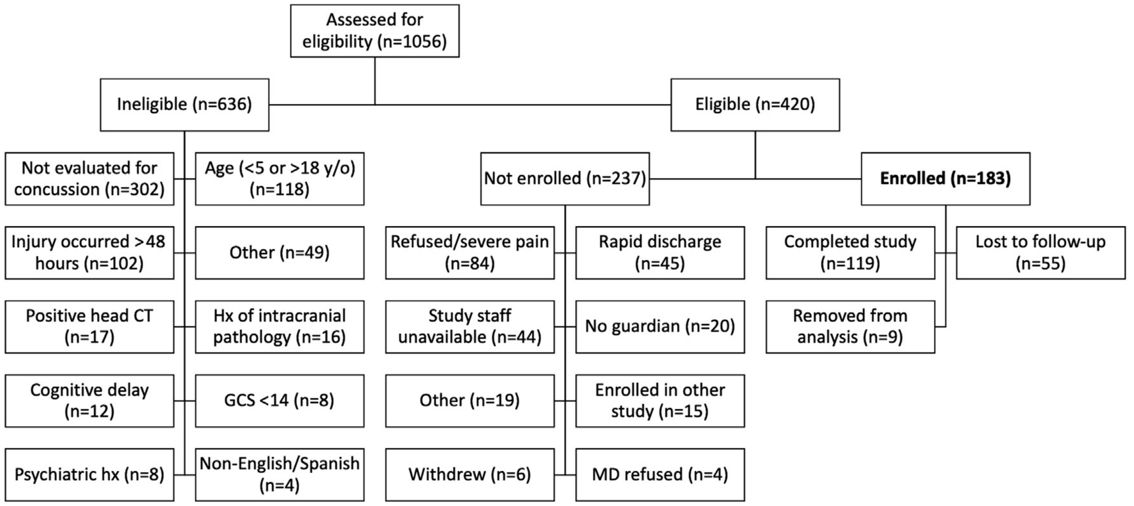

Figure 2. Enrollment flow chart. We assessed 1056 participants for eligibility, of which 420 met eligibility criteria and 183 were enrolled. Of the 636 ineligible patients, more than one-half did not meet specified eligibility criteria, and 302 participants had a head injury without signs and or symptoms of a concussion. *CT*, computed tomography scan; *GCS*, Glasgow Coma Scale; *Hx*, history.

Table I. Demographic data of enrolled subjects

Variables	Moderate cognitive rest (n = 45)	Minimal cognitive rest (n = 74)	*P* value
Age, mean	11.6	10.4	.07
Age group, % (n)			.23
5-7 years old	15.6% (7)	24.3% (18)	
8-12 years old	40.0% (18)	45.9% (34)	
13-18 years old	44.4% (20)	29.7% (22)	
Sex, % (n)			.38
Male	44.4% (20)	52.7% (39)	
Female	55.6% (25)	47.3% (35)	
Mechanism of injury, % (n)			.04
Fall	37.8% (17)	52.7% (39)	
Sports related	35.6% (16)	31.1% (23)	
Bike/motor vehicle collision	8.9% (4)	0% (0)	
Other	17.8% (8)	16.2% (12)	
History of prolonged concussion, % (n) (symptoms ≥1 week)			.60
Yes	15.6% (7)	12.2% (9)	
No	84.4% (38)	87.8% (65)	
History of migraines, % (n) (physician diagnosed)			.81
Yes	7.0% (3)	8.2% (6)	
No	93.0% (40)	91.8% (67)	
Missing	n = 2	n = 1	
Headache, % (n)			.06
Yes	77.8% (35)	60.8% (45)	
No	22.2% (10)	39.2% (29)	
Answering questions slowly, % (n)			.53
Yes	42.4% (19)	36.5% (27)	
No	57.8% (26)	63.5% (47)	
Fatigue, % (n)			.38
Yes	62.2% (28)	54.1% (40)	
No	37.8% (17)	45.9% (34)	
Sensitivity to noise, % (n)			.52
Yes	31.1% (14)	25.7% (19)	
No	68.9% (31)	74.3% (55)	
Balance error scoring system, % (n)			.63
<4	68.9% (31)	73.0% (54)	
≥4	31.1% (14)	27.0% (20)	
Initial PCSI, median	9.0	8.0	.31
Days off school, mean	4.8	1	<.0001
Days off sports, mean	8.3	7.3	.30
Physical rest, % (n) (days off sports)			.01
Minimal (≤2 days)	2.3% (1)	18.2% (12)	
Moderate (>2 days)	97.7% (42)	81.8% (54)	
Missing	n = 2	n = 8	

Table III. Univariate logistic regression analyses of risk factors for persistent postconcussive symptoms

Variables	OR of persistent postconcussive symptoms (95% CI)	*P* value
Age group		
5-7 years old	Reference	
8-12 years old	1.82 (0.46-7.30)	.65
13-18 years old	**5.21 (1.35-20.14)**	**.00**
Sex		
Male	1.25 (0.55-2.86)	.60
Female	Reference	
Mechanism of injury		
Fall	0.40 (0.13-1.19)	.34
Sports related	0.56 (0.18-1.75)	.91
Bike/motor vehicle collision	0.54 (0.05-6.14)	.92
Other	Reference	
History of prolonged concussion (symptoms ≥1 week)		
Yes	**3.27 (1.13-9.47)**	**.03**
No	Reference	
History of migraines (physician diagnosed)		
Yes	2.52 (0.63-10.10)	.19
No	Reference	
Headache		
Yes	**3.04 (1.06-8.68)**	**.04**
No	Reference	
Answering questions slowly		
Yes	1.58 (0.68-3.66)	.29
No	Reference	
Fatigue		
Yes	0.96 (0.42-2.20)	.92
No	Reference	
Sensitivity to noise		
Yes	1.38 (0.56-3.35)	.48
No	Reference	
Balance Error Scoring System		
<4	Reference	
≥4	1.38 (0.56-3.35)	.48
Days off school (continuous)	1.06 (0.89-1.28)	.51
Days off sports (continuous)	1.05 (0.97-1.14)	.23
Cognitive rest (days off school)		
Minimal (≤2 days)	Reference	
Moderate (>2 days)	1.78 (0.76-4.15)	.18
Physical rest (days off sports)		
Minimal (≤2 days)	Reference	
Moderate (>2 days)	4.94 (0.61-39.83)	.13

Bolded values indicate a significance level of less than 0.05.

symptoms of 1.78 (95% CI, 0.76-4.15) and an aOR of persistent postconcussive symptoms of 1.15 (95% CI, 0.44-2.99). Compared with the minimal physical rest group, moderate physical rest had an unadjusted OR of persistent postconcussive symptoms of 4.94 (95% CI, 0.61-39.83) and an aOR of persistent postconcussive symptoms of 3.17 (95% CI, 0.35-28.78).

Discussion

Before the 1940s, 3 weeks of strict bed rest for concussion patients was standard management.[12,32] Furthermore, international consensus concussion guidelines from 2009 and 2012 note that physical and cognitive rest are “the cornerstone of concussion management.”[9,10] Recent studies, however, have led to questions about this management approach and guidelines now support a modified approach with light activity.[16,26]

Overall, our 24% incidence of persistent postconcussive symptoms in our study sample aligns with previous studies on incidence of persistent postconcussive symptoms.[4,33-35] Among our patients, we did not find moderate cognitive or physical rest to be associated with decreased or increased odds of persistent postconcussive symptoms. The only factor associated with persistent postconcussive symptoms in our final multivariable logistic regression model was the 13- to 18-year-old age group. These patients had a more than 5 times higher odds of persistent postconcussive symptoms compared with 5- to 7-year-olds. This finding is consistent with results from a large recent multicenter study on risk factors for persistent postconcussive symptoms and a retrospective study on more than 400 concussed youth, which both found adolescent age associated with persistent postconcussive symptoms.[4,36]

Our results fit with recent studies that did not find an association between cognitive rest and improved recovery time. Thomas et al conducted a randomized trial of 99 pediatric

Table IV. Multivariable logistic regression analysis of risk factors for persistent postconcussive symptoms

Variables	aOR of persistent postconcussive symptoms (95% CI)	*P* value
Age group		
5-7 years old	Reference	
8-12 years old	2.09 (0.40-10.89)	.38
13-18 years old	**5.57 (1.08-28.69)**	**.04**
History of prolonged concussion (symptoms ≥1 week)		
Yes	2.10 (0.60-7.31)	.24
No	Reference	
Headache		
Yes	2.14 (0.68-6.78)	.20
No	Reference	
Cognitive rest (days off school)		
Minimal (≤2 days)	Reference	
Moderate (>2 days)	1.15 (0.44-2.99)	.78
Physical rest (days off sports)		
Minimal (≤2 days)	Reference	
Moderate (>2 days)	3.17 (0.35-28.78)	.31

Bolded values indicate a significance level of less than 0.05.

patients with concussions and found no benefit to strict rest and instead found increased symptom reporting in the rest group at 10-day follow-up.[14] Buckley et al found that 1 day of cognitive and physical rest in student-athletes did not decrease concussion recovery time, and the group that was not told to rest had faster resolution of concussion symptoms.[15] A randomized controlled trial of bed rest for 107 patients with a mild traumatic brain injury with associated posttraumatic amnesia found no significant improvement in symptoms in the bed rest group.[37] A retrospective cohort study of 184 patients from a concussion clinic also found no association with recommendations of cognitive rest and time to recovery.[17]

Our study also did not find an association between physical rest and persistent postconcussive symptoms. Recent studies now support an active approach as a potential mechanism to reduce concussion symptoms and improve recovery time. Leddy et al conducted a randomized trial of 103 adolescents with sports-related concussions and found that those treated with aerobic exercise had a faster recovery than those prescribed stretching and only 4% of adolescents randomized to the aerobic exercise treatment group developed persistent postconcussive symptoms.[25] Kurowski et al performed a randomized trial on 30 adolescents with prolonged concussion symptoms. Their group found that those prescribed subthreshold aerobic exercise had greater improvement in their concussion symptoms scores compared with those prescribed stretching.[24] Additionally, 3 cohort studies found that physical activity level was associated with decreased concussion symptoms.[18,21,22]

Not only does emerging evidence support early return to light activity after an acute concussion, but there are a few proposed mechanisms by which rest could prolong recovery. Rest can lead to significant emotional distress and depression from social restrictions, feelings of isolation, and increased anxiety over falling behind in academic work.[6,12,14] Anxiety and fears over exacerbating symptoms can lead to chronic fatigue and chronic pain, strengthening negative perception of illness and creating a "self-perpetuating cycle."[12] Similarly, framing concussion management with a rest-based treatment approach can lead to the nocebo response, where patients report increased symptomatology owing to an emphasis on the expectation of symptoms.[27] Finally, evidence supports the theory that neurons in the hippocampus may grow with physical activity, while memory is worse with depressed moods.[38] It is possible that rest-related memory impairments could prolong recovery time.

It is important to note that there are significant risks of severe neurologic injury if an athlete returns to contact sports while acutely symptomatic from a concussion. Current guidelines recommend stepwise and gradual return to athletic activities.[26,39]

Our study is not without limitations. Although we were able to recruit more than our goal of 180 patients, about 30% of patients were lost to follow-up, leaving 119 participants in our study. Halfway through the study, we added a small financial incentive to participants for completing the study, which increased our follow-up rate. Nevertheless, the limited sample size may not have allowed us to detect some of the associations that were significant in the univariate logistic regression analyses including history of concussion and headache on initial presentation. Our study was prospective and noninterventional, and concussion management was not standardized across participants. Individual physicians gave recommended management verbally and in printed discharged instructions to each participant. Because participants may not follow the recommendations of their treating provider,[13] the authors decided to track prospectively days off from individual study participants. This strategy is subject to recall bias; participants were asked to recall how many days they took off from school and sports. In future studies, we could consider activity diaries or daily logs to confirm that recall matched actual behavior. Because injury severity has been associated with persistent postconcussive symptoms,[35] we might predict that patients with more severe injuries would self-select to take more time off from school and sports, leading to an increased odds of persistent postconcussive symptoms. Although we did not find significant differences in initial symptom severity between our minimal and moderate cognitive rest groups, a randomized controlled trial rather than a prospective observational study would further minimize this risk. Additionally, our moderate and minimal cognitive rest groups differed slightly based on age, mechanism of injury, and headache at initial presentation, which would be further controlled in a randomized trial.

Our study used days off from school as a proxy for cognitive rest. Although this is not a perfect marker of cognitive rest, school is very likely to be the most rigorous mental activity in which children engaged, and the study team felt it was a reasonable assessment of cognitive activity. Although cognitive and physical rest was once a mainstay of concussion therapy, evidence has emerged that supports early return to light activity, and consensus guidelines have begun to evolve to align with this approach. Our study adds to this management approach; we found that rest from school and sports did not result in a decreased odds of persistent postconcussive symptoms. To determine the effect of rest and exertion on persistent postconcussive symptoms, large randomized controlled trials are required. These studies should continue to examine active management as a potential therapy for acute pediatric concussions to improve recovery time and decrease persistent postconcussive symptoms. ■

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50 Years Ago in *The Journal of Pediatrics*

Magnesium and Birth Asphyxia

Engel RR, Elin RJ. Hypermagnesemia from birth asphyxia. J Pediatr 1970;77:631-7

Engel and Elin reported that there is a correlation between oxygen deprivation, hypermagnesemia, and high potassium levels in both neonates with perinatal asphyxia and anoxic dogs. In view of their finding of elevated magnesium and potassium levels from placental blood after hypoxic deliveries and from dog pups subjected to anoxia, the authors speculated whether magnesium could be used as a marker of perinatal asphyxia from fetal scalp blood.

An increase in potassium post-asphyxia can be explained by the movement of intracellular potassium into the extracellular fluid in the presence of acidosis. This is frequently seen in asphyxiated newborns, and the levels spontaneously decrease as the acidosis improves, unless there is secondary renal failure. Regarding the magnesium levels, more recent publications report both hyper- and hypomagnesemia—but mainly hypomagnesemia, and mainly in samples taken from the neonate and not from the umbilical cord or placenta. That could explain the findings in the study of Engel and Elin. In current practice, when addressing hypomagnesemia or normal levels of magnesium following birth asphyxia, it is standard of care to give magnesium to achieve levels just over normal. The goal is to stabilize the motor membrane and the sodium–potassium–ATPase enzyme system, thus having a favorable effect on seizures and arrhythmia. The findings of Engel and Elin highlight the fact that 50 years later we still do not have all the answers regarding magnesium regulation in asphyxia. It also does highlight how perception and treatment changes, as we now know that magnesium has potentially stabilizing effects, and slightly greater levels than normal might be desirable. Magnesium sulfate ($MgSO_4$) given antenatally is today recommended for perinatal neuroprotection during threatened preterm labor. $MgSO_4$ also has been given postnatally to prevent post-hypoxic brain injury by blocking glutamate receptors within the calcium ion channel without long-term effects in clinical trials. High doses of $MgSO_4$ may trigger hypotension.[1]

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Version 5-7 years old

Instructions: We would like to know if you have had any of these symptoms before your injury. Next, we would like to know if these symptoms have changed after you injury.

I am going to ask you to tell me about your symptom at two points in time: Before the Injury and Yesterday/Today. Interviewer: Please circle only one answer.

	0 = No 1 = A little 2 = A lot	Before the Injury/ Preinjury			Current Symptoms/ Yesterday and Today		
1	Have you had headaches? Has your head hurt?	0	1	2	0	1	2
2	Have you felt sick to your stomach or like you were going to throw up?	0	1	2	0	1	2
3	Have you felt like you might fall when you walk, run or stand?	0	1	2	0	1	2
4	Have you felt dizzy? (like things around you were spinning or moving)	0	1	2	0	1	2
5	Have you felt more tired than usual?	0	1	2	0	1	2
6	Have bright lights bothered you more than usual? (like when you were in the sunglight, when you looked at lights, or watched TV)	0	1	2	0	1	2
7	Have loud noises bothered you more than usual? (like when people were talking, when you heard sounds, watched TV, or listened to loud music)	0	1	2	0	1	2
8	Have you felt grumpy or irritable? (like you were in a bad mood)	0	1	2	0	1	2
9	Have you felt sad?	0	1	2	0	1	2
10	Have you felt nervous or worried?	0	1	2	0	1	2
11	Has it been hard for you to pay attention to what you are doing? (like homework or chores, listening to someone, or playing a game)	0	1	2	0	1	2
12	Has it been hard for you to remember things? (like things you heard or saw, or places you have gone)	0	1	2	0	1	2
13	Have things looked blurry?	0	1	2	0	1	2
	Do you feel "different" than usual?				0	1	2

Figure 1. PCSI scales, divided by age group. *(Continues)*

Version 8-12 years old

Instructions: We would like to know if you have had any of these symptoms before your injury. Next, we would like to know if these symptoms have changed after you injury. Please rate the symptom at two points in time**: Before the Injury/Preinjury** and **Currently**.

Please answer all the items the best that you can. Do not skip any items. Circle the number to tell us how much of a problem this symptom has been for you.

	0 = No 1 = A little 2 = A lot	Before the Injury/ Preinjury			Current Symptoms/ Yesterday and Today		
1	Have you had headaches? Has your head hurt?	0	1	2	0	1	2
2	Have you felt sick to your stomach or nauseous?	0	1	2	0	1	2
3	Have you had any balance problems or have you felt like you might fall when you walk, run or stand?	0	1	2	0	1	2
4	Have you felt dizzy? (like things around you were spinning or moving)	0	1	2	0	1	2
5	Have you felt more tired than usual?	0	1	2	0	1	2
6	Have you felt more drowsy or sleepier than usual?	0	1	2	0	1	2
7	Have bright lights bothered you more than usual? (like when you were in the sunlight, when you looked at lights, or watched TV)	0	1	2	0	1	2
8	Have loud noises bothered you more than usual? (like when people were talking, when you heard sounds, watched TV, or listened to loud music)	0	1	2	0	1	2
9	Have you felt grumpy or irritable? (like you were in a bad mood)	0	1	2	0	1	2
10	Have you felt sad?	0	1	2	0	1	2
11	Have you felt nervous or worried?	0	1	2	0	1	2
12	Have you felt like you are moving more slowly?	0	1	2	0	1	2
13	Have you felt like you are thinking more slowly?	0	1	2	0	1	2
14	Has it been hard to think clearly?	0	1	2	0	1	2
15	Has it been hard for you to pay attention to what you are doing? (like homework or chores, listening to someone, or playing a game)	0	1	2	0	1	2
16	Has it been hard for you to remember things? (like things you heard or saw, or places you have gone)	0	1	2	0	1	2
17	Have things looked blurry?	0	1	2	0	1	2
	Do you feel "different" than usual?				0	1	2

Figure 1. Continued.

Version 13-18 years old

Instructions: We would like to know if you have had any of these symptoms before your injury. Next, we would like to know if these symptoms have changed after you injury. Please rate the symptom at two points in time**: Before the Injury/Preinjury** and **Currently**.

Please answer all the items the best that you can. Do not skip any items. Circle the number to tell us how much of a problem this symptom has been for you.

0 = Not a problem ***3 = Moderate problem*** ***6 = Severe problem***

		Before the Injury/ Preinjury							Current Symptoms/ Yesterday and Today						
1	Headache	0	1	2	3	4	5	6	0	1	2	3	4	5	6
2	Nausea	0	1	2	3	4	5	6	0	1	2	3	4	5	6
3	Balance Problems	0	1	2	3	4	5	6	0	1	2	3	4	5	6
4	Dizziness	0	1	2	3	4	5	6	0	1	2	3	4	5	6
5	Fatigue	0	1	2	3	4	5	6	0	1	2	3	4	5	6
6	Drowsiness	0	1	2	3	4	5	6	0	1	2	3	4	5	6
7	Sensitivity to light	0	1	2	3	4	5	6	0	1	2	3	4	5	6
8	Sensitivity to noise	0	1	2	3	4	5	6	0	1	2	3	4	5	6
9	Irritability	0	1	2	3	4	5	6	0	1	2	3	4	5	6
10	Sadness	0	1	2	3	4	5	6	0	1	2	3	4	5	6
11	Nervousness	0	1	2	3	4	5	6	0	1	2	3	4	5	6
12	Feeling more emotional	0	1	2	3	4	5	6	0	1	2	3	4	5	6
13	Feeling slowed down	0	1	2	3	4	5	6	0	1	2	3	4	5	6
14	Feeling mentally "foggy"	0	1	2	3	4	5	6	0	1	2	3	4	5	6
15	Difficulty concentrating	0	1	2	3	4	5	6	0	1	2	3	4	5	6
16	Difficulty remembering	0	1	2	3	4	5	6	0	1	2	3	4	5	6
17	Visual problems (double vision, blurring)	0	1	2	3	4	5	6	0	1	2	3	4	5	6
18	Get confused with directions or tasks	0	1	2	3	4	5	6	0	1	2	3	4	5	6
19	Move in a clumsy manner	0	1	2	3	4	5	6	0	1	2	3	4	5	6
20	Answer questions more slowly than usual	0	1	2	3	4	5	6	0	1	2	3	4	5	6

In general, to what degree do you feel differently than before the injury (not feeling like yourself)? **No Difference 0 1 2 3 4 Major Difference**

Circle your rating with "0" indicating "Normal" (No Difference) and "4" indicating "Very Different" (Major Difference)

Figure 1. Continued.

Table II. Demographic data of enrolled vs lost to follow-up

Variables	Enrolled (n = 119)	Lost to follow-up (n = 55)	*P* value
Age, mean	10.9	11.2	.54
Age group, % (n)			.77
5-7 years old	21.0% (25)	16.4% (9)	
8-12 years old	43.7% (52)	47.3% (26)	
13-18 years old	35.3% (42)	36.4% (20)	
Sex, % (n)			.03
Male	49.6% (59)	67.3% (37)	
Female	50.4% (60)	32.7% (18)	
Mechanism of injury, % (n)			.01
Fall	47.1% (56)	54.5% (30)	
Sports related	32.8% (39)	20.0% (11)	
Bike/motor vehicle collision	3.4% (4)	16.4% (9)	
Other	16.8% (20)	9.1% (5)	
History of prolonged concussion, % (n) (symptoms ≥1 week)			.90
Yes	13.4% (16)	12.7% (7)	
No	86.6% (103)	87.3% (48)	
History of migraines, % (n) (physician diagnosed)			.04
Yes	7.8% (9)	18.2% (10)	
No	92.2% (107)	81.8% (45)	
Missing	n = 3		
Headache, % (n)			.08
Yes	67.2% (80)	80.0% (44)	
No	32.8% (39)	20.0% (11)	
Answering questions slowly, % (n)			.95
Yes	38.7% (46)	38.2% (21)	
No	61.3% (73)	61.8% (34)	
Fatigue, % (n)			.90
Yes	57.1% (68)	58.2% (32)	
No	42.9% (51)	41.8% (23)	
Sensitivity to noise, % (n)			.85
Yes	27.7% (33)	29.1% (16)	
No	72.3% (86)	70.9% (39)	
Balance Error Scoring System, % (n)			.94
<4	71.4% (85)	70.9% (39)	
≥4	28.6% (34)	29.1% (16)	
Initial PCSI, median	9.0	8.0	.67
Days off school,* mean	2.4	2.1	.40
Cognitive rest,* % (n) (days off school)			.24
Minimal (≤2 days)	62.6% (74)	72.5% (29)	
Moderate (>2 days)	37.8% (45)	27.5% (11)	
Missing		n = 15	
Days off sports,* mean	7.7	7.2	.60
Physical rest,* % (n) (days off sports)			.17
Minimal (≤2 days)	11.9% (13)	21.1% (8)	
Moderate (>2 days)	88.1% (96)	78.9% (30)	
Missing	n = 10	n = 17	

*Days off from school and sports was not available for some of enrolled and lost to follow-up participants.