Supplementary Online Content

Zemek RL, Farion KJ, Sampson M, McGahern C. Prognosticators of persistent symptoms following pediatric concussion: a systematic review. *JAMA Pediatrics*. Published online January 7, 2013. doi:10.1001/2013.jamapediatrics.216.

eAppendix 1. Electronic search strategies
eAppendix 2. Bibliography of references included for qualitative analysis
eTable. Persistent concussive symptoms outcomes following pediatric concussion

This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Electronic search strategies

MEDLINE
1. Post-Concussion Syndrome/
2. ((post or persistent or unresolved or delayed) adj4 concuss*).mp. or postconcuss$.tw.
3. (commotio cerebri or post traumatic encephalopathy).mp. or ((Post commotion or post contusion or post head injury) adj2 syndrome$).tw. or post traumatic syndrome$.tw. or shell shock$.tw.
4. Brain Concussion/ or Brain Injury, Chronic/
5. ((post or persistent or unresolved or delayed) adj4 (brain or skull or head or injury)).mp.
6. 4 and 5
7. or/1-3,6
8. (child$ or adolescent$ or infan$).mp.
9. 7 and 8
10. remove duplicates from 9

Embase
1. Postconcussion Syndrome/
2. ((post or persistent or unresolved or delayed) adj4 concuss*).mp. or postconcuss$.tw.
3. (commotio cerebri or post traumatic encephalopathy).mp. or ((Post commotion or post contusion or post head injury) adj2 syndrome$).tw. or post traumatic syndrome$.tw. or shell shock$.tw.
4. exp Concussion/
5. ((post or persistent or unresolved or delayed) adj4 (concuss* or brain or skull or head or injury)).mp.
6. 4 and 5
7. or/1-3,6
8. (child$ or adolescent$ or infan$ or pediatr$ or paediatr$).mp.
9. 7 and 8
10. limit 9 to embase
11. remove duplicates from 10

Cochrane Databases
1. "post concussive" or "post concussion"
2. postconcuss* or post-concuss*
3. "Post commotion" or "post contusion" or "post head injury" or "post traumatic encephalopathy" or "post traumatic syndrome" or "Post-commotion" or "post-contusion" or "post-head injury" or "post-traumatic encephalopathy" or "post-traumatic syndrome" or "Postcommotion" or "postcontusion" or "posthead injury" or "posttraumatic encephalopathy" or "posttraumatic syndrome"
4. (#1 OR #2 OR #3)

Note: “Search All Text” used for each search statement.

eAppendix 2. Bibliography of References Included for Qualitative Analysis

Barlow K, Crawford S, Stevenson A, Sandhu S, Belanger F, Dewey D. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. Pediatrics 2010;126(2):e37-e381.[12]
The following study duplicated patient-level data from Barlow KM (2010):

> Barlow K, Crawford S, Sandhu S, Dewey D. Predicting post-concussion syndrome at three months after a mild traumatic head injury in children. J Neurotrauma. 2009 Conference: 2nd Joint Symposium of the National and International Neurotrauma Societies Santa Barbara, CA United States. Conference Start: 20090907 Conference End: 20090911. Conference Publication: A83.[49]

Barlow M, Schlabach D, Peiffer J, Cook C. Differences in change scores and the predictive validity of three commonly used measures following concussion in the middle school and high school aged population. Int J Sports Phys Ther 2011;6(3):150-7.[30]

Barr W, Prichep L, Chabot R, Powell M, McCrea M. Measuring brain electrical activity to track recovery from sport-related concussion. Brain Inj 2012;26(1):58-66.[31]

Cimpello LB, Byczkowski TL, Bazarian JJ (2011). Predictors of post-concussion syndrome in children. Acad Emerg Med 2011. Annual meeting of the Society for Academic Emergency Medicine, SAEM Boston. Conference Pub S181.[32]
The following study duplicated patient-level data from Cimpello et al. (2011):

> Babcock CL, Byczkowski TL, Bazarian JJ. Acute predictors of postconcussion syndrome (PCS). Clinical and Translational Science (2011). Conference 2011 Clinical and Translational Research and Education Meeting. Conference Pub 98.[33]

Covassin T. Elbin RJ, Nakayama Y. Tracking neurocognitive performance following concussion in high school athletes. Phy Sportsmed 2010;38:87-93.[34]

Falk A, Von Wendt L, Derkvist B. The specificity of post-concussive symptoms in the pediatric population. J Child Health Care 2009;13(3):227-38.[35]
The following study duplicated patient-level data from Falk et al. (2009):

> Falk A, Von Wendt L, Klang B. The specificity of post-concussive symptoms in the pediatric population. Brain Inj 2010;24(3):115–463. (Abstract).[36]

Keightley M, Reed N, Green S, et al. Recovery from sports-related concussion in a pediatric population Brain Injury. 2010 Conference: 8th World Congress on Brain Injury of the International Brain Injury Association Washington, DC United States. 210-211.[37]

Korinthenberg R, Schreck J, Weser J, Lehmkuhl G. Post-traumatic syndrome after minor head injury cannot be predicted by neurological investigations. Brain & Devel 2004;26(2):113-7.[38]

Lau B, Collins M, Lovell M. Sensitivity and specificity of subacute computerized neurocognitive testing and symptom evaluation in predicting outcomes after sports-related concussion. Am J Sports Med 2011;39(6):1209-16.[50]
The following study duplicated patient-level data from Lau et al. (2011):

> Lau B, Kontos A, Collins M, Mucha A, Lovell M. Which on-field signs/symptoms predict protracted recovery from sports-related concussion among high school football players? The American Journal of Sports Medicine 2011;39:2311-8.[51]

Lee M, Fine B. Adolescent concussions. Connecticut Medicine 2010;74(3):149-56.[40]

Ponsford J, Willmott C, Rothwell A, et al. Cognitive and behavioral outcome following mild traumatic head injury in children. J Head Trauma Rehabil 1999;14(4):360-72.[41]

Sroufe N, Fuller D, West B, Singal B, Warschausky S, Maio R. Postconcussive symptoms and neurocognitive function after mild traumatic brain injury in children. Pediatrics 2010;125(6):e1331-9.[42]

Thomas D, Collins M, Saladino R, Frank V, Raab J, Zuckerbraun N. Identifying neurocognitive deficits in adolescents following concussion. Acad Emerg Med 2011;18(3):246-54.[43]

Yeates K, Luria J, Bartkowski H, Rusin J, Martin L, Bigler E. Postconcussive symptoms in children with mild closed head injuries. J Head Trauma Rehabil 1999;14(4):337-50.[11]

Yeates KO , Taylor, HG, Rusin, J, et al. Longitudinal trajectories of post-concussive symptoms in children with mild traumatic brain injuries and their relationship to acute clinical status. *Pediatrics 2009*; 123(3): 735-743.[39]

The following studies duplicated patient-level data from Yeates et al. (2009):

Fay T, Yeates K, Taylor H, et al. Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. J Int Neuropsychol Soc 2010;16(1):94-105.[44]

Hajek C, Yeates K, Taylor G, et al. Relationships among post-concussive symptoms and symptoms of PTSD in children following mild traumatic brain injury. Brain Inj 2010; 24(2):100-9.[45]

Hajek C, Yeates K, Taylor G. Agreement between parents and children on ratings of post-concussive symptoms following mild traumatic brain injury. Child Neuropsychol 2011;7:17-33.[46]

Moran LM, Taylor HG, Rusin J, et al. Do postconcussive symptoms discriminate injury severity in pediatric mild traumatic brain injury? J Head Trauma Rehabil 2011;26:348-54.[47]

Taylor H, Dietrich A, Nuss K, et al. Post-concussive symptoms in children with mild traumatic brain injury. Neuropsychol 2010;24(2):148-59.[48]

Yeates KO, Kaizar E, Rusin J, et al. Reliable change in postconcussive symptoms and its functional consequences among children with mild traumatic brain injury. Arch Pediatr Adolesc Med 2012; 166(7):615-622.[64]

eTable. Persistent Concussive Symptoms Outcomes Following Pediatric Concussion

First Author (Year)	Primary Outcome	Intervention / Key Features	Results	Conclusion (Secondary objective: predictors of safe return to sport)
Babcock Cimpello LB (2011)[32,33]	Determine incidence of PCS and clinical variables associated with PCS	Variables collected in ED and 3 month follow-up call collected Rivermead Post-Concussion Symptom Questionnaire. PCS defined as >=3 symptoms that were worse than pre-mTBI.	29.9% of patients had PCS at 3 months. Compared to children who recovered, patients with PCS were significantly: Older (14.4 vs. 12.7) Hx LOC (61 vs. 50%) Present with headache (84 vs. 66%) Nausea/vomit (44 vs. 33%) Require CT imaging (63 vs. 49%) Require admission (17 vs. 8%) Multivariate analysis showed only age and HA were associated with PCS. N/V was also significant if HA removed from model.	PCS rates were greater in older children with a history of loss of consciousness and either headache or nausea/vomiting .
Barlow KM (2009)[12,49]	Comparison of mild traumatic brain injury group (mTBI) vs. children with extracranial (e.g. orthopedic) injuries	Post Concussion Symptoms Inventory (1, 3, 6 months) Rivermead Postconcussion Symptoms Questionnaire (1, 3, 6 months)	1 month post injury, 58.5% mTBI cases symptomatic vs. 38.5% extracranial controls 3 months post injury, 11% mTBI cases symptomatic (13.7% for > 6 years old) vs. 0.5% (1% for >6 years old) extracranial control	9% of all children with mTBI met ICD-10 criteria for PCS at 3 months Older children more likely to have PCS Supportive that PCS exists (no difference in family functioning between groups (Family Assessment Device) nor maternal psychological adjustment (Brief Symptoms Inventory))

First Author (Year)	Primary Outcome	Intervention / Key Features	Results	Conclusion (Secondary objective: predictors of safe return to sport)
Barlow KM (2009)[12,49] (continued)			Symptoms at 2-weeks which predicted symptoms for 3-month duration were frequent headaches (p=0.005), being more emotional (p=0.03) and being more tired or fatigued (p<0.001) The main pre-injury predictor was a past history of headaches (p=0.03)	
Barlow MD (2011)[30]	Determine the validity for post-concussion syndrome (PCS) of the Post-Concussion Symptom Scale (PCSS), Balance Error Scoring System (BESS), and Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)	Enrolled patients needed minimum two visits at clinic in which full testing (PCSS, BESS, ImPACT) was completed.	55% male with PCS 46% female with PCS No baseline score predicts if post-concussion syndrome will occur.	Low concurrent validity between changes in scores. The use of a battery of tests to assess recovery and return to play is most discriminative.
Barr W (2012)[31]	To use an electroencephalographic (EEG) index of quantitative brain activity to follow recovery from concussion	Handheld portable EEG recordings from cases and controls measured at the time of injury from sideline, day 8 and day 45 post injury Measured Concussion Symptom Inventory (CSI), Standardized Assessment of Concussion (SAC), Balance Error Scoring System (BESS), Automated Neuropsychological Assessment Metrics (ANAM)	While group differences for CSI and SAC at time of injury, no significant difference at day 8 or day 45 between cases and controls MTBI-DS (EEG Index score) showed more injury at time of injury and at day 8, but no significant difference at day 45.	Physiologic changes (EEG) were detected after reported recovery of symptom and cognitive functioning following sport related concussion.

First Author (Year)	Primary Outcome	Intervention / Key Features	Results	Conclusion (Secondary objective: predictors of safe return to sport)
Covassin T (2010)[34]	Compare baseline neurocognitive performance with postconcussion neurocognitive performance	All patients had baseline neurocognitive performance (ImPACT) prior to injury. ImPACT testing repeated (verbal memory, visual memory, processing speed, reaction time, and total symptom scores) on days 2, 7, 14, 21, and 30 post concussion.	Significantly slower reaction times (day 14), verbal memory impairment (day 7), motor processing speed (day 7) and symptom scores (day 2).	High school athletes may take >14 days to return to baseline levels for reaction time.
Falk AC (2009)[35,36]	Compare symptoms at baseline and presentation between mild head injured group and abdominal complaint group.	Rivermead Post-Concussion Questionnaire (translated) Karolinska Post Concussion Questionnaire for <5 years (developed by authors)	No significant differences between groups at 3 months. [Note: follow-up rates of 43% (mTBI) and 33% (control).]	No significant differences between groups at 3 months.
Keightley M (2010)[37]	Document both acute and long-term recovery following sports-related concussion in male and female children 10-14 years old.	Post-concussion Symptoms Scale – Revised (PCS) cognitive, motor and visuomotor tasks	Pre-injury data collected on 100 youth hockey players; 11 with subsequent concussion. Recovery (defined as a return to a score ≤ 6 on the PCS scale) ranged from 1 to 38 days post-concussion. All participants demonstrated poorer cognitive performance compared to pre-injury baseline performance when tested upon full symptom resolution.	In-depth assessment and follow-up should be used to monitory recovery since cognitive performance deficits existed beyond symptom resolution.
Korinthenberg R (2004)[38]	To determine predictive factors of post-traumatic	Neurological, EEG and psychological investigations	At baseline there was correlation between	Authors doubt the utility of performing and EEG in patients experiencing a

	syndrome in children	within 24 h with follow-up	EEG and somatic	mild head trauma with LOC<10 min.
First Author (Year)	**Primary Outcome**	**Intervention / Key Features**	**Results**	**Conclusion (Secondary objective: predictors of safe return to sport)**
Korinthenberg R (2004)[38] (continued)	following minor head injury	4– 6 weeks post-injury.	symptom score (headache, dizziness, nausea, vomiting, fatigue). At 4-6 week follow-up, 23% still had somatic symptoms, 18% with psychiatric symptoms, and 10% with neurological symptoms. However, baseline EEG did not predict follow-up symptoms persistence.	
Lau B (2011)[50,51]	To determine which on-field signs and symptoms were predictive of a protracted versus rapid recovery. A secondary analysis assessed if ImPACT testing added to prognostic ability of prolonged symptoms. (43b)	On-field signs and symptoms of concussion were observed and recorded Immediate Post-concussion Assessment and Cognitive Test (ImPACT) including PCSS was assessed with 2.23 days of injury.	Dizziness at time of injury was associated with prolonged recovery (OR=6.34 (95% CI: 1.34-29.91). No other on-field symptoms were associated with increased risk. The combination of 4 symptom clusters and 4 neurocognitive composite scores had highest sensitivity (65%), specificity (80%) in predicting protracted recovery.	On-field dizziness is predictive of increased risk of prolonged recovery. Combining symptom scores with acute computerized neurocognitive testing improved sensitivity of predicting prolonged recovery as compared to using symptom scores alone.
Lee MA (2010)[40]	To review the etiology, mechanism, symptoms, and recovery period of concussion.	Patient reported symptoms Prolonged cases defined as abnormal ImPACT testing beyond 4 weeks post injury	24.4% of patients with persistent symptoms beyond 4 weeks A history of receiving multiple hits to the head in the same game was most predictive of	Multiple blows to the head occurring initially predicts prolonged recovery.

			persistent symptoms (33% vs. 23%, p=0.01)	
First Author (Year)	**Primary Outcome**	**Intervention / Key Features**	**Results**	**Conclusion (Secondary objective: predictors of safe return to sport)**
Ponsford J (1999)[41]	To investigate which factors were associated with cognitive and behavioral outcomes at 3 months post-injury. Secondary objective to examine if early 1 week follow-up reduced incidence of problems.	Postconcussion Syndrome Checklist (PCSC) Westmead PTA scale kids >7 years (orientation, memory) Children's Orientation and Amnesia Test (COAT) < 7 years Child Behavior Checklist Rowe Behavioral Rating Inventory Peabody Picture Vocabulary Test Vineland Adaptive Behavior Scale Intervention = additional visit at 1 week plus information book, coping advice	1 week post-injury, patients with head injury with greater headache. 3 months post injury, patients with head injury with significantly lower memory and verbal scores compared to controls. Rowe Behavioral Rating Inventory was predictive of symptoms at 3 months	Patients with prolonged symptoms were more likely to have a history of previous head injury, learning difficulties, behavioral problems.
Sroufe NS (2010)[42]	To compare frequency, nature, and recovery trajectory of PCSs and neurocognitive function in the initial 4 to 5 weeks after MTBIs to other pediatric injuries.	Clinical data obtained from the pediatric ED attending/fellow physician or fellow Baseline assessments completed in the ED, and reassessment at 1 and 4-5 weeks after injury: Post-Concussion Symptom Questionnaire (PCSQ) Children's Orientation and Amnesia Test (COAT) Test of Memory Malingering (TOMM) Neurocognitive tests (Single Digit Modalities Test=SDMT, Trail-making Test Part B = TMTB, Ray	Concussion symptoms persisted up to 5 weeks after MTBIs, with a significant decrease between 1 and 4 to 5 weeks after injury. MTBIs demonstrated different recovery patterns than did control group participants on the Trail-making Test Part B with group difference (p=0.03)	mTBI patients more symptoms at all times than control group. Trail-making Test Part B with significant difference on pattern of recovery

		Auditory Verbal Learning Test=RAVALT)		
First Author (Year)	**Primary Outcome**	**Intervention / Key Features**	**Results**	**Conclusion (Secondary objective: predictors of safe return to sport)**
Thomas DM (2011)[43]	To determine if computerized neurocognitive testing (Immediate Postconcussion Assessment and Cognitive Test [ImPACT]) in the ED correlated with recovery	Acute Concussion Evaluation (ACE) and Impact Follow-up telephone surveys at 3-day, 2-week, 6-week, and 3 month post-injury.	ED-obtained symptom measures (ACE and ImPACT PCSS) did not correlate with follow-up outcome measures (time to return to normal activity and follow-up ImPACT scores). Concussion grading using the AAN and Cantu scales (grade 1, 2 or 3) was not associated with variation seen in follow-up outcome measures (time to return to normal activity; 2-day, 2-week, or 6-week postconcussive symptoms; and follow-up ImPACT score). Median time to symptom resolution was 21 days (IQR = 6–28)	ImPACT testing in the ED helps predict neurocognitive deficits seen in follow-up, but there was no observed association between overall ED ImPACT scores and time to return to normal activity. Neurocognitive assessment in the ED detected deficits that clinical grading could not and correlated with deficits at follow-up. The majority of patients had longer than 2 weeks of postconcussive symptoms. No association found between activities (e.g., sleep, physical activity, school attendance) and recovery times.
Yeates KO (1999)[11]	To examine incidence, neuropsychological, behavioral and neuroimaging correlates of PCS in children with mild closed head injury	MRI Neuropyschological testing at baseline and 3 months post injury. Health and Behavior Inventory (62-item)	Children with head injury had PCS symptoms (Mean=6.6 cognitive, 3.1 somatic) compared to siblings (4.5, 1.8 respectively). Cases also had more attention problems and tiredness than siblings.	Premorbid and post-injury factors are believed to contribute to PCS. PCS indicates an acquired impairment of brain function.
Yeates KO (2009)[39,44-48,64]	To examine PCS in children with mTBI across the first year post-injury	Health and Behavior Inventory (50-item) Post-Concussive Symptom Interview Baseline,1, 3, and 12-month	LOC was associated with PCS (p =0.007). Motor-vehicle related trauma was also associated with PCS	Children with mTBI have persistent symptoms different than those with orthopedic injury. Somatic symptoms (specifically headaches, dizziness, and feelings of

		follow-ups	(p=0.002]. The presence of headaches, being	the room spinning) showed the strongest correlation with discriminant scores.
First Author (Year)	**Primary Outcome**	**Intervention / Key Features**	**Results**	**Conclusion (Secondary objective: predictors of safe return to sport)**
Yeates KO (2009)[39,44-48,64] (continued)			forgetful, having difficulty in concentrating, and tiring easily scores were most discriminant between mTBI and orthopedic injury.	