DEVELOPMENTAL NEUROPSYCHOLOGY
https://doi.org/10.1080/87565641.2017.1334785

Increased Symptom Reporting in Young Athletes Based on History of Previous Concussions

Rosemarie Scolaro Moser[a] and Philip Schatz[b]

[a]Sports Concussion Center of New Jersey, Princeton, New Jersey; [b]Department of Psychology, Saint Joseph's University, Philadelphia, Pennsylvania

ABSTRACT
Research documents increased symptoms in adolescents with a history of two or more concussions. This study examined baseline evaluations of 2,526 younger athletes, ages 10 to 14. Between-groups analyses examined Post Concussion Symptom Scale symptoms by concussion history group (None, One, Two+) and clusters of Physical, Cognitive, Emotional, and Sleep symptoms. Healthy younger athletes with a concussion history reported greater physical, emotional, and sleep-related symptoms than those with no history of concussion, with a greater endorsement in physical/sleep symptom clusters. Findings suggest younger athletes with a history of multiple concussions may experience residual symptoms.

Introduction

Background

The high profile public health problem of sports-related concussion is no longer just the territory of American football games and Hollywood studios (IMDb, 2016; Montopoli, 2013; Moser, 2007). The potentially long lasting sequelae of repeated concussion have been documented in the adult and college populations (Guskiewicz, et al, 2003; Covassin, Stearne, & Elbin, 2008; Iverson, Echemendia, Lamarre, Brooks, & Gaetz, 2012) as well as in high school athletes (Moser & Schatz, 2002; Moser, Schatz, & Jordan, 2005; Schatz, Moser, Covassin, & Karpf, 2011). All 50 states in the United States (US) have adopted some type of legislation to address the problem of youth concussion (NCPIC, 2016; Simon & Mitchell, 2016). Indeed, in the US, from 2005 to 2009, pediatric patients sustaining a mild traumatic brain injury (mTBI) made up more than 2 million outpatient visits and almost 3 million emergency department (ED) visits (NCIPC, 2016).

Most of the available concussion research has focused on adults, collegiate athletes, and high school-aged adolescents. It is well-recognized that there is a paucity of concussion research in the younger, prehigh school athlete population (McCrory et al., 2013; Meehan, Taylor, & Proctor, 2011) as well as a lack of evidence-based research on diagnosis, treatment, and management of concussion (Kirkwood, Yeates, & Wilson, 2006; McCrory, Collie, Anderson, & Davis, 2004; NCIPC, 2016). As a result, existing guidelines and protocols for adults and adolescents are often applied to prepubescent children, despite knowledge that the adolescent brain is still developing (Casey, Jones, & Hare, 2008) and that youth may recover from traumatic brain injury differently than adults (Anderson, Catroppa, Morse, Haritou, and Rosenfeld (2005). However, the research examining whether concussions affect individuals differently depending on age has revealed no difference in symptom presence and severity between younger and older adolescents (Lee, Odom, Zuckerman, Solomon, &

CONTACT Rosemarie Scolaro Moser Ph.D., ABN, ABPP-RP rmoser@sportsconcussionNJ.com Sports Concussion Center of New Jersey, 281 Witherspoon Street, Suite 230, Princeton, NJ 08540.

Sills, 2013) and age not emerging as a significant predictor of concussion outcome (Meehan, Mannix, Monuteaux, Stein, & Bachur, 2014).

Objective

Decreased scores on cognitive testing (Moser et al., 2005) and greater symptom reporting (Schatz et al., 2011) have been documented in healthy high school athletes with 2 or more previous concussions. In the present paper, we sought to extend previous research investigating symptom reporting in a sample of healthy pre-high school children, ages 10 to 14, participating in athletics. Specifically, we hypothesized that younger, prehigh school students would report more concussion-related symptoms as a function of their concussion history.

Method

Study Design

Institutional Review Board approval was obtained for retrospective analysis of de-identified data. As this was a cross-sectional, retrospective study of a multi-center de-identified database/convenience sample, patient consent was not required and the study size was already determined. The STROBE statement checklist for reporting of observational, cross-sectional studies was consulted for reporting of results (Strobe Statement, 2016).

Participants

Participants were extracted from a large, multi-center (school-hospital-concussion clinic) database, where predominantly group testing had been conducted. The sample included 2,526 10 to 14 year old pre-high school student athletes (mean age = 11.9, *SD* = 1.0) who completed pre-season baseline neurocognitive assessments between June 2010 and February 2016 and were included. These athletes participated in athletic programs that administered baseline testing as part of their pre-season activities. In those cases where a participant may have completed two successive baselines in consecutive or staggered years, only the first baseline was recorded for analysis. Prior to compiling of multi-site data, participants were excluded on the basis of:

(1) having "invalid" baseline scores, as flagged as "Baseline ++" (approximately 6% of cases), representing those cases that fall below predetermined cut-offs reflective of performance below the 5th percentile. For more information refer to Schatz, Moser, Solomon, Ott, and Karpf (2012),
(2) having a previous diagnosis of a learning disability or attention deficit disorder (approximately 7% of cases), or
(3) having sustained a concussion within the past 6 months (for athletes in the 1 or 2+ previous concussion groups; approximately 1% of cases).

This yielded a sample of 2,600 athletes. Athlete were further excluded if they had a self-reported history of epilepsy/seizures (*N* = 18; 0.7% of cases), brain surgery (*N* = 6; 0.3%), meningitis (N = 8; 0.3%), substance or alcohol use (*N* = 7; 0.3%), or psychiatric treatment (*N* = 39; 1.5%). The athletes were assigned to independent groups on the basis of concussion history: zero (*N* = 1189), one (*N* = 1146), or two or more (*N* = 191 previous concussions). Age and gender distributions are presented in Table 1.

Table 1. Group demographics.

	0 (*N* = 1,189)	1 (*N* = 1,146)	2+ (*N* = 191)
*Sex**			
Male	648 (41.0%)	785 (49.6%)	149 (9.4%)
Female	540 (57.3%)	361(38.3%)	42 (4.5%)
Age**	11.9 (0.9)	12.0 (1.0)	12.1 (0.9)

Note. Sex and Learning Problems data presented as *N* (%), Age data presented as Mean (*SD*)
*$\chi^2(2) = 69.1$; $p = .001$.
** $F(2,2523) = 4.67$; $p = .009$.

Data sources and variables

Athletes completed the Post-Concussion Symptom Scale (PCSS) during pre-season baseline evaluations as part of the computer-based Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test battery (Lovell, 2013). The Total Symptom Score is the sum of scores on the 22-item, 7-point Likert-type Post-Concussion Symptom Scale. Athletes rate their perceived severity of 22 symptoms from 0 (not experiencing) to 6 (severe). The 22 items include: headache, nausea, vomiting, balance problems, dizziness, fatigue, trouble falling asleep, sleeping more than usual, sleeping less than usual, drowsiness, sensitivity to light, sensitivity to noise, irritability, sadness, nervousness, feeling more emotional, numbness or tingling, feeling slowed down, feeling mentally "foggy," difficulty concentrating, difficulty remembering, and visual problems.

Past research has employed factor analysis to investigate preseason, baseline symptom clusters on the ImPACT Post-Concussion Symptom Scale (Lau, Collins, & Lovell, 2011); Kontos et al., 2012). There are four symptom clusters that have been identified: physical symptoms (e.g., headache, dizziness, balance problems), cognitive symptoms (e.g., difficulty concentrating, fogginess, cognitive slowing), emotional symptoms (e.g., sadness, more emotional, irritability), and sleep symptoms (e.g., difficulty falling asleep, sleeping less than usual; see Table 2) (Lau et al., 2011).

Statistical Methods

Two multivariate analyses of variance (MANOVAs) were conducted, using the following dependent variables: (a) all 22 symptoms and (b) symptoms grouped into physical, emotional, cognitive, and sleep symptom clusters.

Because the ImPACT Manual (Lovell, 2013) does not provide PCSS normative data for athletes younger than high school ages, sample-based means and standard deviations were used to calculate standardized scores (Z-scores) for individual symptom reporting. Athletes were dichotomized to groups based on: (a) having symptoms within 1 SD from the mean, or (b) having symptoms >1 SD from the mean. Likelihood of self-reporting or endorsing symptoms was assessed using a chi-square analyses to identify the likelihood of symptom endorsement greater than the sample mean, as a function of concussion history. All analyses were conducted using SPSS, Version 23 (Statistical

Table 2. Symptoms by physical, cognitive, emotional, and sleep clusters.[22]

Physical	Cognitive	Emotional	Sleep
• Headache	• Feeling mentally "foggy"	• Irritability	• Drowsiness
• Nausea	• Feeling slowed down	• Sadness	• Sleeping less than usual
• Vomiting	• Difficulty concentrating	• More emotional	• Sleeping more than usual
• Balance Problems	• Difficulty remembering	• Nervousness	• Trouble falling asleep
• Dizziness			
• Visual Problems			
• Fatigue			
• Sensitivity to light			
• Sensitivity to noise			
• Numbness/Tingling			

Package for the Social Sciences IBM Corporation, 2015). *A priori* statistical significance was set at $P < .05$ for MANOVAs, and $P < .0125$ for Chi-Square analyses; exact P values are documented.

Results

Descriptive Data

In this sample, 7.6% of youth athletes had sustained two or more concussions, 45.4% had sustained one concussion, and 47.1% reported no history of concussion. Thus, 53% of the sample had sustained at least one concussion by the age of 10 to 14. Male athletes were significantly more likely to have sustained one (49.6% vs. 38.3%) or two or more (9.4% vs. 4.5%) previous concussions than females, whereas female athletes were more likely to have no history of concussion (57.3% vs. 41.0%; $X^2(2) = 69.1$, $p < .001$). There was a small but statistically significant difference between concussion groups with respect to age ($F(2,2523) = 4.67$; $p = .009$), although the mean age range by group was only 11.9 to 12.1. Distribution by sport is presented in Table 3

Outcome Data & Main Results

MANOVA (Wilks Λ) revealed a significant multivariate effect of concussion history group on concussion-related symptoms at baseline ($F(44,5004) = 1.56$; $P = .011$). Subsequent univariate and post hoc analyses revealed youth athletes with a history of 2 or more concussions endorsed higher ratings on headache, dizziness, fatigue, sleeping more, sleeping less, sensitivity to light, irritability, and feeling more emotional than their peers with a history of 1 or no concussion (Table 4). MANOVA (Wilks Λ) of symptom clusters revealed a significant multivariate effect of concussion history group on concussion-related symptom clusters at baseline ($F(8,5040) = 3.29$ $p = .001$). Subsequent univariate and post hoc analyses revealed youth athletes with a history of 1 or 2 or more concussions endorsed more physical and sleep symptom clusters than their peers with a history of no concussion (Table 5).

After symptom scores were dichotomized to reflect whether an athlete endorsed symptoms greater than 1 *SD* from the sample mean, X^2 analyses revealed that athletes with previous concussions were significantly more likely to endorse symptoms within the physical, emotional, and sleep symptom clusters, but not within the cognitive cluster (Table 6).

Table 3. Sport participation by concussion history group.

Sport	*None	*1	*2±	Total**
Football	451 (37.9%)	531 (46.3%)	89 (46.6%)	1071 (42.4%)
Soccer	166 (14.0%)	172 (15.0%)	24 (12.6%)	362 (14.3%)
Volleyball	130 (10.9%)	72 (6.3%)	8 (4.2%)	210 (8.3%)
Basketball	74 (6.2%)	82 (7.2%)	11 (5.8%)	167 (6.6%)
Cheerleading	68 (5.7%)	36 (3.1%)	10 (5.2%)	114 (4.5%)
Ice Hockey	40 (3.4%)	51 (4.5%)	9 (4.7%)	100 (4.0%)
Field Hockey	41 (3.4%)	17 (1.5%)	2 (1.0%)	60 (2.4%)
Cross Country	37 (3.1%)	29 (2.5%)	7 (3.7%)	73 (2.9%)
Baseball	21 (1.8%)	22 (1.9%)	10 (5.2%)	53 (2.1%)
Track & Field	23 (1.9%)	15 (1.3%)	2 (1.0%)	44 (1.6%)
Softball	27 (2.3%)	12 (1.0%)	0 (0.0%)	39 (1.5%)
Lacrosse	10 (0.8%)	19 (1.7%)	6 (3.1%)	35 (1.4%)
Swimming	17 (1.4%)	9 (0.8%)	3 (1.6%)	29 (1.1%)
Tennis	15 (1.3%)	9 (0.8%)	0 (0.0%)	24 (1.0%)
Other	22 (1.8%)	31(2.7%)	3 (1.6%)	56 (2.2%)
Unknown	47 (4.0%)	39 (3.4%)	7 (3.7%)	93 (3.7%)

*represents the *N* (%) out of the group
**Total denotes the percentage out of 2,526 athletes.

Table 4. Concussion symptoms by concussion history group.

Symptom	None	1	2±	F	sig
Physical					
Headache	.24 (0.8)	.34 (0.9)	.52 (1.1)	9.7	.001
Nausea	.06 (0.4)	.05 (0.4)	.07 (0.4)	0.2	.85
Vomit	.05 (0.4)	.09 (0.5)	.10 (0.4)	2.0	.14
Balance Problems	.04 (0.3)	.07 (0.4)	.08 (0.4)	2.9	.06
Dizziness	.08 (0.4)	.13 (0.6)	.19 (0.7)	5.0	.007
Visual Problems	.09 (0.4)	.12 (0.5)	.13 (0.5)	1.6	.120
Fatigue	.32 (1.2)	.41 (1.4)	.47 (1.7)	3.8	.02
Sensitive to Light	.12 (0.5)	.19 (06)	.23 (0.7)	6.6	.001
Sensitive to Noise	.05 (0.4)	.07 (0.5)	.02 (0.5)	2.5	.09
Numbness/ Tingling	.06 (0.3)	.08 (0.4)	.02 (0.1)	1.7	.19
Cognitive					
Feeling Mentally Foggy	.08 (0.4)	.08 (0.4)	.08 (0.4)	0.1	.88
Feeling Slowed Down	.03 (0.3)	.05 (0.3)	.04 (0.3)	0.6	.54
Difficulty Concentrating	.16 (0.6)	.21 (0.7)	.22 (0.6)	1.8	.16
Difficulty Remembering	.09 (0.5)	.11 (0.5)	.12 (0.5)	0.6	.20
Emotional					
Irritability	.10 (0.5)	.16 (0.7)	.22 (0.7)	5.2	.005
Sadness	.28 (0.8)	.28 (0.8)	.22 (0.7)	0.7	.50
Feeling More Emotional	.10 (0.5)	.16 (0.6)	.19 (0.7)	3.5	.03
Nervousness	.11 (10.5)	.12 (0.6)	.12 (0.6)	0.4	.69
Sleep					
Drowsiness	.05 (0.4)	.11 (0.5)	.17 (0.6)	8.0	.001
Trouble Falling Asleep	.13 (0.6)	.19 (0.6)	.19 (0.7)	2.7	.07
Sleeping More than Usual	.09 (0.5)	.15 (0.7)	.16 (0.6)	3.2	.04
Sleeping Less than Usual	.23 (0.8)	.30 (0.9)	.37 (0.8)	3.3	.04

Note. scores presented as Mean (*SD*).
$F(44,5004) = 1.56$; $p = .011$.

Table 5. Concussion symptom clusters by concussion history group.

Symptom Cluster	None	1	2±	F	sig
Physical	1.10(2.8)	1.55 (3.5)	1.91 (3.6)	8.83	.001
Cognitive	0.36 (1.4)	0.45 (1.4)	0.47 (1.3)	1.36	.26
Emotional	0.58 (1.7)	0.72 (1.9)	0.74 (1.9)	1.83	.16
Sleep	0.51 (1.5)	0.74 (1.7)	0.87 (1.7)	9.17	.001

Note. scores presented as Mean (*SD*).
$F(8,5040) = 3.30$; $p = .001$.

Table 6. Percentage of athletes endorsing symptoms >1 *SD* above the mean, by cluster and concussion group.

Symptom Cluster	None (%)	1 (%)	2± (%)	X^2	sig
Physical	22.9	30.4	36.3	25.6	.001
Cognitive	13.7	17.4	18.8	7.4	.020
Emotional	14.0	17.9	20.9	9.6	.008
Sleep	14.7	283.1	26.2	32.4	.001

Discussion

Key Results & Interpretation

Previous findings, from a large sample of high school students, identified approximately 59% of athletes with a history of one or more concussions (Moser et al., 2005). The present study revealed a similar figure, with over half the athletes in this large group of 10 to 14 year olds (53%). However, the percentage of high school students with more than one concussion in the former study was 17% compared to 7.6% in the present study of younger athletes. In this regard, it seems that although younger and older youth athletes may have similar rates of having sustained at least one concussion in the past, the younger group has a lower percentage of athletes with a history of more than one concussion. This is not surprising, given that as athletes age and increase their athletic exposures, so too does potential for sustaining concussions increase. Nevertheless, these percentages should give us pause as it appears that by age 10 or so, approximately 50% of younger athletes have sustained a concussion.

Importantly, the present results reveal concerns that concussions sustained prior to high school may result in symptom-based residuals. It is clear that otherwise healthy athletes who have sustained concussions report more symptoms than their concussion-free peers. We know that major developmental changes in brain structures and thought processing occur during puberty (Casey et al, 2008; Piaget & Inhelder, 1969). The implications are yet unknown as to how concussion may affect brain maturation during this critical period of development. In addition, otherwise "healthy" high school athletes have been shown to self-report concussion-related symptoms (Asken, Snyder, Clugston, Gayner, Sullan, & Bauer, 2017; Iverson & Lange, 2003), with increased symptom reporting with high school athletes with pre-existing conditions (Iverson et al., 2015). Perhaps most importantly, these "healthy" athletes have symptom profiles consistent with International Classification of Diseases 10th Revision (ICD-10) diagnoses (Asken et al., 2017), especially diagnoses of post-concussion syndrome (Iverson & Lange, 2003; Iverson et al., 2015). The current data show that 20–35% of otherwise healthy athletes, ages 10–14 endorse concussion-related symptoms, even when using a sample-specific cut-off of 1 SD above the mean.

Notably, none of the four symptoms within the Cognitive cluster exhibited a statistically significant difference related to concussion history, and only two of the four symptoms in the Emotional cluster demonstrated any statistically significant difference. It may be that athletes in this age group are developmentally less insightful regarding their cognitive and emotional status. They may more easily think of symptoms in a concrete or tangible manner, such as somatically (physical-sleep), rather than abstractly as in thought (cognition) or feeling (emotional). Or perhaps youngsters do not fully understand the meaning of concepts such as "mentally foggy" or "slowed down." Indeed, brain structures for understanding abstract concepts are thought to develop in adolescence (Anderson et al., 2005; Piaget & Inhelder, 1969) and thus postconcussion symptom checklists that are used in adolescent and adult populations may not be well-suited for pre-high school, middle school youth. In fact, the psychometric evidence for use of symptom scales in with adolescents has been shown to be stronger than with younger children (Gioia, Schneider, Vaughan, & Isquith, 2009). These findings provide further support for the use of more age appropriate symptom checklists.

Regarding concern about the possible greater susceptibility of females to concussion (Dick, 2009); Covassin, Swanik, & Sachs, 2003), the present study revealed that females experienced a lower rate of concussion in this age group. It is unclear how to interpret this finding. It could be that females may begin their sports careers later than males such that by the time of age 10 to 14, males may have had greater contact exposure and risk. Alternatively, the effect of hormones on brain structures may differentiate the pre-adolescent versus adolescent female's susceptibility to concussion (Wunderle, Hoeger, Wasserman, & Bazarian, 2014).

Limitations

The present study is not without limitations. While these young athletes were assigned to groups retrospectively, the design is quasi-experimental. Despite including a group with no previous concussion, there is a lack of a formal control group. In addition, while no athletes had sustained a concussion within the 6 months prior to baseline testing, there was no control or analysis for time since concussion (beyond the 6-month cut-off), which may be a variable that could influence these results. In addition, the analyses relied upon subjective self-report which could be influenced by factors such as fear of restriction to play and a hesitancy to report concussion or symptoms. Also, as discussed above regarding age appropriateness, the use of the PCSS in this younger group may have obscured possible findings. Furthermore, as concussion history was self-reported, it is not known whether parent questionnaires or in-person clinical interviews may have rendered different symptom reporting. Nevertheless, this is the first study to document greater symptoms in otherwise healthy 10–14 year olds who have a history of concussion. There is tremendous controversy within the scientific and academic communities regarding the possible sequelae of multiple concussions in adults. There may be a number of contributing factors to the current results, such as greater familiarity with concussion symptoms and nomenclature, based on previous exposure to concussion symptom checklists (for athletes with a concussion history). However, there may be implications for the current findings in younger athletes, as they may be reflective of early signs of effects of multiple concussions. At the very least, adults who are responsible for youth sports should be aware of the potential long term effects of exposing youth athletes to multiple concussions prior to high school. Although these differences may seem subtle in this younger age group, future research may well focus on how these differences become manifest at a later age and affect future lives.

Conclusions

This study sought to identify the incidence of symptom reporting at baseline in 10–14 year old, pre-high school youth athletes on the basis of concussion history. As this was a large, multi-center sample, these results may well be generalizable to the greater population of pre-high school youth. Findings revealed that over half of the athletes in this age group had sustained one or more concussions. Importantly, in these otherwise healthy youth, those with a history of concussion reported more symptoms than their peers with no history of concussion. The high incidence of concussion and greater symptom reporting in these youngsters with a history of concussion, at an important time of brain development, should be seriously considered in the context of youth sports and youth concussion management. The implications for future academic and career performance as well as quality of life are unknown.

Acknowledgments

Preliminary report of this study was presented as a poster at the International Consensus Conference on Concussion In Sport, Berlin, October 27-28, 2016.

References

Anderson, V., Catroppa, C., Morse, S., Haritou, F., & Rosenfeld, J. (2005). Functional plasticity or vulnerability after early brain injury. *Pediatrics*, *116*(6), 1374–1382. doi:10.1542/peds.2004-1728

Asken, B. M., Snyder, A. R., Clugston, J. R., Gaynor, L. S., Sullan, M. J., & Bauer, R. M. (2017). Concussion-like symptom reporting in non-concussed collegiate athletes. *Archives Clinical Neuropsychol, Mar*, *10*, 1–9. doi:10.1093/arclin/acx018

Casey, B. J., Jones, R. M., & Hare, T. A. (2008). The adolescent brain. *Annals NY Academy of Science,(1124)*, 111–126. doi:10.1196/annals.1440.010

Concussion. (2015). *IMDB*. Retrieved November 5, 2016, from http://www.imdb.com/title/tt3322364/

Covassin, T., Stearne, D., & Elbin, R. (2008). Concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes. *Journal of Athletic Training*, *43*(2), 119–124. doi:10.4085/1062-6050-43.2.119

Covassin, T., Swanik, C. B., & Sachs, M. L. (2003). Sex differences and the incidence of concussions among collegiate athletes. *Journal of Athletic Training*, *38*(3), 238–244.

Dick, R. W. (2009). Is there a gender difference in concussion incidence and outcomes? *British Journal of Sports Medicine*, *43*(Suppl 1), i46–i50. doi:10.1136/bjsm.2009.058172

Gioia, G. A., Schneider, J. C., Vaughan, C. G., & Isquith, P. K. (2009). Which symptom assessments and approaches are uniquely appropriate for paediatric concussion? *British Journal of Sports Medicine, 43(Supp 1)*, i13–i22. doi:10.1136/bjsm.2009.058255

Guskiewicz, K. M., McCrea, M., Marshall, S. W., Cantu, R. C., Randolph, C., Barr, W., Onate, J. A. & Kelly, J. P. (2003). Cumulative effects associated with recurrent concussion in collegiate football players: The NCAA concussion Study. *Jama*, *26*(10), 1217–1225.

IBM. (2015). *Statistical package for the social science: IBM SPSS for macintosh, version 23*. Armonk, NY: IBM Corp.

Iverson, G. L., Echemendia, R. J., Lamarre, A. K., Brooks, B. L., & Gaetz, M. B. (2012). Possible lingering effects of multiple past concussions. *Rehabilitation Research and Practice*, *2012*, 1–7. doi:10.1155/2012/316575

Iverson, G. L., & Lange, R. T. (2003). Examination of "postconcussion-like" symptoms in a healthy sample. *Appl Neuropsychol*, *10*(3), 137–144. doi:10.1207/S15324826AN1003_02

Iverson, G. L., Silverberg, N. D., Mannix, R., Maxwell, B. A., Atkins, J. E., Zafonte, R., & Berkner, P. D. (2015). Factors associated with concussion-like symptom reporting in high school athletes. *JAMA Pediatrics*, *169*(12), 1132–1140. doi:10.1001/jamapediatrics.2015.2374

Kirkwood, M. W., Yeates, K. O., & Wilson, P. E. (2006). Pediataric sport-related concussion in children: A review of the clinical management of an oft-neglected population. *Pediatrics*, *117*(4), 1359–1371. doi:10.1542/peds.2005-0994

Kontos, A. P., Elbin, R. J., Schatz, P., Covassin, T., Henry, L., & Pardini, J. (2012). A revised factor structure for the post-concussion symptom scale: Baseline and postconcussion factors. *American Journal of Sports Medicine*, *40*(10), 2374–2384. doi:10.1177/0363546512455400

Lau, B. C., Collins, M. W., & Lovell, M. R. (2011). Sensitivity and specificity of subacute computerized neurocognitive testing and symptom evaluation in predicting outcomes after sports-related concussion. *American Journal of Sports Medicine*, *39*(6), 1209–1216. doi:10.1177/0363546510392016

Lee, Y. M., Odom, M. J., Zuckerman, S. L., Solomon, G. S., & Sills, A. K. (2013). Does age affect symptom recovery after sports-related concussion? A study of high school and college athletes. *Journal of Neurosurgery Pediatrics*, *12*(6), 537–544. doi:10.3171/2013.7.PEDS12572

Lovell, M. R. (2013). *ImPACT technical manual: Online ImPACT 2007–2012* (Vol. 2013). Pittsburgh, PA: ImPACT Applications.

McCrory, P., Collie, A., Anderson, V., & Davis, G. (2004). Can we manage sport related concussion in children the same as in adults? *British Journal of Sports Medicine*, *38*(5), 516–519. doi:10.1136/bjsm.2004.014811

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvorak, J., Echemendia, R., Engebretsen, L., Johnston, K., Kutcher, J.S., Raftery, M., Sills, A., Benson, B.W., Davis, G.A., Ellenbogen, R.G., Guskiewicz, K., Herring, S.A., Iverson, G.L., Jordan, B.D., Kissick, J., McCrea, M., McIntosh, A.S., Maddocks, D., Makdissi, M., Purcell, L., Putukian, M., Schneider, K., Tator, C.H., Turner, M. (2013). Consensus statement on concussion in sport: The 4th international conference on concussion in sport held in Zurich, November 2012. *British Journal of Sports Medicine*, *47*(5), 250–258. doi:10.1136/bjsports-2013-092313

Meehan, W. P., Mannix, R., Monuteaux, M. C., Stein, C. J., & Bachur, R. G. (2014). Early symptom burden predicts recovery after sport-related concussion. *Neurology*, *83*, 2204–2210. doi:10.1212/WNL.0000000000001073

Meehan, W. P., Taylor, A. M., & Proctor, M. (2011). The pediatric athlete: Younger athletes with sport-related concussion. *Clinics in Sports Medicine*, *30*(1), 133–x. doi:10.1016/j.csm.2010.08.004

Montopoli, B. (2013, August 23). ESPN drops involvement in concussion documentary; NFL denies applying pressure. *CBS News*. Retrieved November 5, 2016, from http://www.cbsnews.com/news/espn-drops-involvement-in-concussion-documentary-nfl-denies-applying-pressure/

Moser, R. S. (2007). The growing public health concern of sports concussion: The new psychology practice frontier. *Professional Psychology: Research and Practice*, *38*(6), 699–704. doi:10.1037/0735-7028.38.6.699

Moser, R. S., & Schatz, P. (2002). Enduring effects of concussion in youth athletes. *Archives of Clinical Neuropsychology*, *17*(1), 91–100. doi:10.1093/arclin/17.1.91

Moser, R. S., Schatz, P., & Jordan, B. (2005). Prolonged effects of concussion in high school athletes. *Neurosurgery*, *57*(2), 300–306. doi:10.1227/01.NEU.0000166663.98616.E4

National Center for Injury Prevention and Control (NCIPC). 2016. September 7. *Report from the pediatric mild traumatic brain injury guideline work group: Systematic and draft clinical recommendations for health care providers*. Atlanta, GA: Centers For Disease Control and Prevention.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child*. New York, NY: Basic Books.

Schatz, P., Moser, R. S., Covassin, T., & Karpf, R. (2011). Early indicators of enduring symptoms in high school athletes with multiple previous concussions. *Neurosurgery*, *68*(6), 1560–1567. doi:10.1227/NEU.0b013e31820e382e

Schatz, P., Moser, R. S., Solomon, G. S., Ott, S. D., & Karpf, R. (2012). Prevalence of invalid computerized baseline neurocognitive test results in high school and college athletes. *Journal of Athletic Training*, *47*(3), 289–296. doi:10.4085/1062-6050-47.3.14

Simon, L. M., & Mitchell, C. N. (2016). Youth concussion laws across the Nation: Implications for the traveling team physician. *Current Sports Medicine Reports.*, *15*(3), 161–167. doi:10.1249/JSR.0000000000000268

Von Elm, E., Althman, D. G., Egger, M., Pocock, S. J., Gotzche, P. C., Vandenbroucke, J. P., & Strobe Initiative. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines fro reporting observational studies. British Journal of Medicine, 335(7624), 806–808.

Wunderle, K., Hoeger, K. M., Wasserman, E., & Bazarian, J. J. (2014). Menstrual phase as a predictor of outcome after mild traumatic brain injury in women. *Journal of Head Trauma Rehabilitation*, *29*(5), E1–E8. doi:10.1097/HTR.0000000000000006