Title

Gender Differences in Concussion and Postinjury Cognitive Findings in an Older and Younger Pediatric Population

Authors

Tanveer, Sarah

Zecavati, Nassim

Delasobera, Elizabeth Bronson

et al.

Publication Date

2017-05-01

DOI

10.1016/j.pediatrneurol.2017.02.001

Peer reviewed

Pediatric Neurology 70 (2017) 44–49

Contents lists available at ScienceDirect

Pediatric Neurology

journal homepage: www.elsevier.com/locate/pnu

Original Article

Gender Differences in Concussion and Postinjury Cognitive Findings in an Older and Younger Pediatric Population

Sarah Tanveer BS, Nassim Zecavati MD, MPH, Elizabeth Bronson Delasobera MD, Temitayo Oyefunmike Oyegbile MD, PhD *

ABSTRACT

BACKGROUND: Studies have documented gender differences associated with concussion. The purpose of this study was to determine if these gender differences are also noted within a pediatric population. **METHODS:** This prospective study analyzed 1971 patients who had completed preconcussion and postconcussion neuropsychological testing within the Washington, DC, area. **RESULTS:** Our results showed that children and adolescents with concussion exhibit gender differences with respect to risk factors, recovery, and symptomatology. Females are more likely to present with a concussion ($P < 0.001$), experience more discomfort from a concussion ($P < 0.001$), and seek treatment for postconcussive headaches ($P < 0.001$). On the other hand, males are more likely to sustain a concussion from a contact sport ($P < 0.001$) and experience loss of consciousness, confusion, and amnesia with a concussion more frequently than females ($P < 0.001$). Postconcussive cognitive function also differs by gender. Both males and females exhibit a decline in cognitive testing compared with baseline ($P < 0.001$); however, visual memory ($P = 0.02$) is more affected in females than in males. These findings remain unchanged among pediatric patients aged ≥14 years; however, no gender differences were noted in individuals aged ≤13 years. **CONCLUSION:** It is important for health care providers, schools, athletic trainers, and coaches to be aware of these gender differences associated with concussion in order to provide adequate surveillance and appropriate monitoring and support during the recovery period.

Keywords: gender, concussion, cognitive testing, pediatric

Pediatr Neurol 2017; 70: 44-49

Introduction

Of the millions of youths who participate in sports yearly within the United States, approximately two million children and adolescents sustain concussions, accounting for over 160,000 emergency room visits and hospitalizations annually.[1-5] Female enrollment in sports has steadily increased over the past ten years.[6,7] Furthermore, females sustain concussions as do males and for any given sport, females may actually be more likely to sustain a concussion than males.[6,7,10,13] There may also be notable gender differences in symptoms of concussions,[9,13,17,19,21,23,24] specifically in postconcussive headaches and cognitive function, which suggests that there may conceivably be gender differences in treatment and recovery times as well.

The current guidelines for diagnosis and treatment of concussion do not differ between males and females in spite of the evidence that there may be clinically significant gender differences. This lack of difference is likely due to limited documentation available on gender differences in concussion. A clear characterization of these gender differences in concussion is imperative to assist with tailoring accurate and adequate concussion diagnosis and treatment to each individual.

Most of the evidence available on gender differences in concussion relies on the findings primarily gathered from an older adolescent population who are mostly high school or college athletes. Gender differences in a younger population of children and young adolescents have not been well established yet, as older adolescents are more often involved

The authors have no affiliations with or financial interest in any testing instruments discussed in this manuscript.

Article History:
Received August 2, 2016; Accepted in final form February 2, 2017

* Communications should be addressed to: Dr. Oyegbile; Pediatric Neurology; Sleep Medicine & Epilepsy; MedStar Georgetown University Hospital; 4200 Wisconsin Ave NW; Washington, DC 20016.
E-mail address: Temitayo.O.Oyegbile@gunet.georgetown.edu

0887-8994/$ – see front matter © 2017 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.pediatrneurol.2017.02.001

in organized sports compared with younger children. Furthermore, within the limited literature addressing gender differences in postconcussive symptoms, few have addressed neuropsychological outcomes following a concussion in females compared with males.[9,20,21] Addressing these gaps in the literature is necessary to fully characterize the gender differences in concussion.

The objectives of this study were twofold. First, we aimed to assess for gender differences in the incidence of concussion, postconcussive symptoms, and cognitive function in a pediatric population. Second, we aimed to characterize the effect of age on these gender differences in postconcussive symptoms and cognitive function.

We evaluated males and females of school age ranging from elementary school to college years within the Washington, DC, area before and after sustaining a concussion. Within the Washington, DC, area, many schools require baseline concussion testing with sports clearance by a physician or athletic trainer before the start of the sports season and require individuals to return to the clinic for evaluation and clearance after sustaining a concussion. In this prospective study, our patients were seen within the MedStar Georgetown University Hospital system in the pediatric and sports medicine clinics and completed the concussion evaluation. The testing includes a comprehensive neurocognitive battery in addition to an assessment on postconcussive symptoms. Within our unique model, these patients serve as their own healthy controls. These data have been collected prospectively over the past six years, resulting in a database of almost 2000 patients.

Methods

Study setting and design

Pediatric patients were seen for preconcussion evaluations in the MedStar Georgetown University Hospital from January 2010 to May 2016. When patients returned with a possible concussion, the concussion was diagnosed by one of the five physicians who were either sports medicine specialists or pediatric neurologists in the outpatient sports medicine and/or pediatric neurology concussion clinic at the MedStar Georgetown University Hospital. These patients underwent clinical reevaluation and repeat concussion testing following the diagnosis of a sports-related concussion. A total of 1971 concussion evaluation sessions were included in the study, 1276 preconcussion sessions and 695 postconcussion sessions. This study was approved by the Georgetown University Institutional Review Board (IRB ID# 2015-0807).

Participants

Patients ranged in age from ten to 20 years at the time of the initial cognitive testing, and they completed the subsequent cognitive testing at the clinic within one day to four weeks after injury. Most (~87%) of the patients were seen within three days of injury. The patient data consisted primarily of middle school, high school, and college-aged patients who had participated in multiple sports (Table 1). Patients were assigned randomized subject ID numbers to protect their identifying information in compliance with the institutional review board requirements.

Data collection

Preconcussion and postconcussion symptoms were assessed through clinical examination and a neuropsychological battery test: Immediate Postconcussion Assessment and Cognitive Assessment (ImPACT). This is a computer-based test that assesses an individual's cognitive function and cumulatively documents current concussion symptoms measured by the Post-Concussion Symptoms Scale. The test was administered via a web-enabled desktop computer and with the assistance of a clinical nurse, medical assistant, or resident or fellow who has undergone test administration training.

TABLE 1.
Breakdown of Sports Activities Associated With Individuals With Concussion

Sport	Total (%)	Males (%)	Females
Football	**118 (28)**	**118 (49.2)**	
Lacrosse	86 (20.4)	51 (21.3)	35 (19.3)
Soccer	44 (10.5)	20 (8.3)	24 (13.3)
Cheerleading	39 (9.3)		**39 (21.5)**
Field hockey	29 (6.9)		29 (16.0)
Basketball	28 (6.7)	11 (4.6)	17 (9.4)
Rugby	18 (4.3)	16 (6.7)	2 (1.1)
Volleyball	17 (4.0)		17 (9.4)
Baseball	11 (2.6)	11 (4.6)	
Softball	10 (2.4)		10 (5.5)
Ice hockey	9 (2.1)	9 (3.8)	
Diving	4 (0.6)		4 (2.2)
Swimming	2 (0.5)		2 (1.1)
Track and field	1 (0.2)		1 (0.6)
Martial arts	1 (0.2)	1 (0.4)	
Wrestling	1 (0.2)	1 (0.4)	
Rowing	1 (0.2)	1 (0.4)	
Road biking	1 (0.2)	1 (0.4)	
Boxing	1 (0.2)		1 (0.6)
No sport	274	122	152
Total	695	362	333

Highest rates are indicated in bold.

This test is a neuropsychological screening test that helps health care providers oversee the recovery progress in injured individuals within a clinical setting. The neurocognitive assessment consists of a demographic questionnaire, concussion symptom inventory, and a neurocognitive performance test. The data obtained from the neurocognitive component examined variables such as reaction time, processing speed, verbal memory, visual memory, and total symptoms score.[11]

Briefly, the testing has been shown to be specific and sensitive, as well as reliable and valid.[11-14] The reliability, validity, and testing instructions have been rigorously studied. Furthermore, this testing shows construct validity,[14] indicating that the test battery is an accurate and reliable measure of neurocognitive performance.

Six neuropsychological test modules measuring the cognitive domains of attention, memory, reaction time, and processing speed are administered via computer testing. The testing takes less than 25 minutes. Final scores from each of the modules are presented in four composite cognitive domains: verbal memory, visual memory, processing speed, and reaction time. In addition, this test provides an "Impulse Control" composite score that screens for invalidity by measuring the number of errors committed during the testing. Higher scores on verbal and visual memory and motor processing speed indicate a better performance. Verbal and visual memory scores are presented as a percentage. Motor processing speed is presented as a composite score. A lower score on reaction time indicates a better performance. All reaction time scores are presented in seconds.

In addition to the cognitive testing, the software uses a 22-item scale, the Post-Concussion Symptom Scale, which is used to test the severity of concussion symptoms. Patients rate their current symptom severity on a seven-point Likert scale, whereby 0 is asymptomatic and 7 is the most severe. All 22 items are then summed to produce the total symptom score evaluating 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.

Data were obtained from a prospective dataset of concussion injury reports from patients seen by Georgetown University physicians utilizing the testing database.

Analyses

All data obtained were collated using the Statistical Package for Social Sciences (SPSS) software (Version 21.0, IBM, Chicago, IL). Items were recoded to numeric values to conduct statistical computations. The total symptom score and all cognitive scores were initially log transformed. Univariate analysis of covariance (ANCOVA) was used to evaluate for gender differences among neuropsychological testing scores and concussion symptom severity. The independent variable used in this study was gender and the dependent variables were the five log-transformed composite scores (verbal, visual memory, and motor processing speed, visual motor and total symptom score). Overall, our analyses make a comparison of premorbid and postconcussion scores. Age was included as a covariate to address potential confounding effects in all analyses. Sport was initially included as a covariate but was removed as analyses revealed it to be noncontributory. The alpha level was set at $P = 0.05$, with a targeted minimum Cohen's d effect size of 0.2. least significant difference *post-hoc* tests were used for individual comparisons. Risk analyses testing and Pearson's correlations were also utilized.

Results

Our study included a total of 1971 testing sessions, 1276 preconcussion sessions conducted as a baseline and 695 postconcussion sessions conducted in patients who returned with a concussion. The ages ranged from ten to 20 years; the average age was 17.1 years. In our subject pool, 139 patients were diagnosed with attention-deficit disorder or attention-deficit hyperactivity disorder; 33 patients reported having dyslexia and three patients have autism. There were five reported individuals with substance abuse. Lastly, six patients had reported a history of epilepsy. Including these factors as covariates in the analyses did not change our findings.

Gender differences in sports

The group was 57% male. Sports injuries were the most common cause of concussions in our study. The sports included lacrosse, soccer, American football, cheerleading, field hockey, equestrian, softball, road and mountain biking, volleyball, baseball, basketball, swimming, tennis, martial arts, rugby, ice hockey, boxing, track and field, skiing, wrestling, rowing, cross country, diving, and boating.

In the assessment of males and females combined, the highest total reported cases of concussion were as follows: football (n = 118), lacrosse (n = 86), soccer (n = 44), cheerleading (n = 39), field hockey (n = 29), basketball (n = 28), rugby (n = 18), volleyball (n = 17), baseball (n = 11), softball (n = 10), ice hockey (n = 9), diving (n = 4), swimming (n = 2), track and field (n = 1), road biking (n = 1), rowing (n = 1), martial arts (n = 1), wrestling (n = 1), and boxing (n = 1), and lastly those who were not involved in a sport (n = 274) (Table 1).

The highest total reported cases of concussion among males came from football (n = 118) (Table 1). Following this, lacrosse (n = 51), soccer (n = 20), rugby (n = 16), basketball (n = 11), baseball (n = 11), ice hockey (n = 9), martial arts (n = 1), wrestling (n = 1), rowing (n = 1), road biking (n = 1), and were not involved in a sport (n = 122).

The highest total reported cases of concussion from females came from cheerleading (n = 39), followed by lacrosse (n = 35), field hockey (n = 29), soccer (n = 24), volleyball (n = 17), basketball (n = 17), softball (n = 10), cross country (n = 10), diving (n = 4), swimming (n = 2), rugby (n = 2), track and field (n = 1), and were not involved in a sport (n = 152) (Table 1).

Gender differences in concussion incidence and symptoms

Among the patients with concussion, females had a higher rate of returning with a concussion than their male counterparts compared with baseline (relative risk = 1.31, 95% confidence interval = 1.16, 1.48, $P < 0.001$) (Table 2). Males were more likely to sustain a concussion from a contact sport (68%) than a noncontact sport (32%), whereas females did not differ in their likelihood to sustain a concussion from a noncontact sport (44%) versus a contact sport (56%) (odds ratio = 0.61, 95% confidence interval = 0.52, 0.73, $P < 0.001$). Interestingly, males were more likely than females to experience loss of consciousness ($F(1,725) = 11.58$, $P = 0.001$), confusion ($F(1,691) = 21.83$, $P < 0.001$), amnesia of the event ($F(1,725) = 18.28$, $P < 0.001$), and amnesia after the event ($F(1,691) = 14.11$, $P < 0.001$) compared with females.

In spite of this, the female total symptom score was higher after sustaining a concussion than the male total symptom score ($F(1,689) = 19.9$, $P < 0.001$) (Fig 1). It is important to note that males and females had similar symptom scores at baseline ($F(1,536) = 1.97$, $P = 0.16$) but differed in the intensity of concussion symptoms after sustaining a concussion. Females were also more likely to seek out treatment for headaches ($F(1,569) = 7.7$, $P = 0.006$) and migraines ($F(1,590) = 6.35$, $P = 0.012$) compared with their male counterparts.

Concussion and cognition

Baseline and postconcussive cognitive scores were directly compared initially without accounting for gender. Overall, patients in our study performed significantly worse on cognitive testing after sustaining a concussion compared with baseline performance in verbal memory ($F(1,1969) = 69.1$, $P < 0.001$), visual memory ($F(1,1969) = 84.4$, $P < 0.001$), and impulse control ($F(1,1969) = 22.13$, $P < 0.001$) (Figs 2 and 3). There were no significant differences in reaction time ($F(1,1969) = 0.29$, $P = 0.59$) and visual motor testing ($F(1, 1969) = 0.67$, $P = 0.41$) between baseline performance and postconcussion testing.

When evaluated by gender, both males and females had poorer verbal memory, visual memory, and impulse control after sustaining a concussion compared with baseline. Furthermore, both males and females had no significant

TABLE 2.
Ratio of Males and Females Who Return With a Concussion Compared With Baseline

Ratio of Returns	Females	Males	Frequency
Preconcussion	479	797	1276
Postconcussion	333	362	695
Total	812	1159	1971

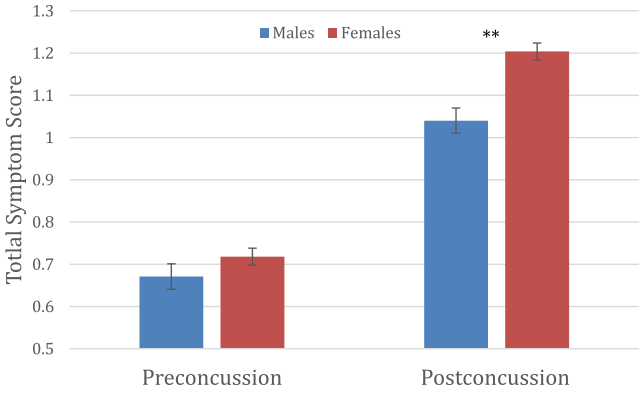

FIGURE 1.
Concussed females experienced a higher level of concussion symptoms than concussed males. $^{**}P < 0.001$. (The color version of this figure is available in the online edition.)

differences in visual motor and reaction time performance when comparing baseline with postconcussive testing.

Gender comparison of postconcussive cognitive function

Postconcussive male and female cognitive scores were directly compared. After sustaining a concussion, females performed significantly poorly on visual memory testing compared with males ($F(1,889) = 13.1$, $P < 0.001$) (Fig 4), whereas there was no difference at baseline ($F(1,1201) = 2.23$, $P = 0.136$). No significant differences were found in other cognitive measures in concussed individuals.

Gender differences by age

We evaluated gender differences in individuals 13 years and younger. Interestingly, there were no significant gender differences in concussed individuals younger than 13 years. There were no differences in the total symptom score in individuals younger than 13 years ($F(1,129) = 1.46$, $P = 0.246$). Furthermore, there were no significant cognitive differences by gender; however, there was a trend toward significance in verbal memory ($F(1,119) = 2.07$, $P = 0.065$) such that females performed poorly on verbal memory testing compared with males after a concussion.

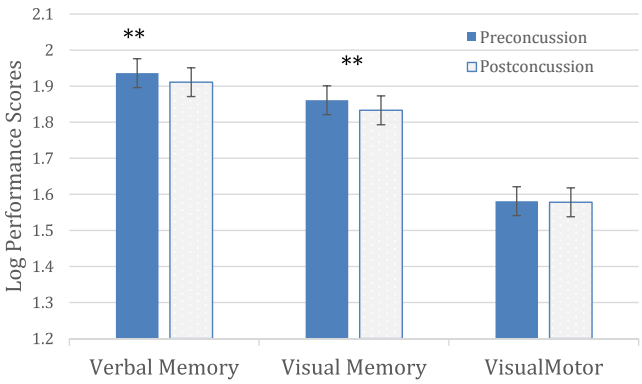

FIGURE 2.
Concussed individuals perform worse on verbal memory and visual memory compared with baseline testing. $^{**}P < 0.05$. (The color version of this figure is available in the online edition.)

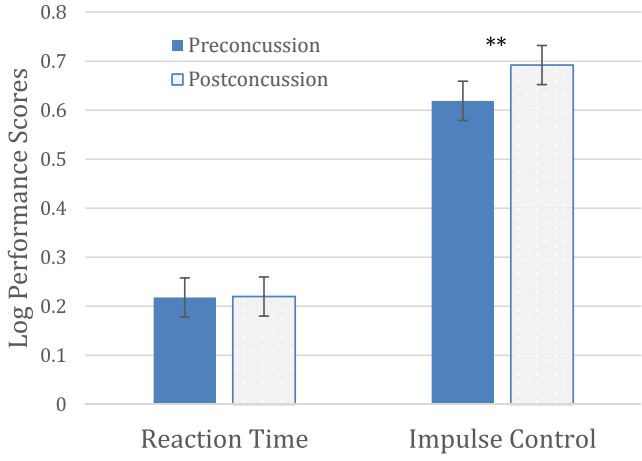

FIGURE 3.
Concussed individuals perform worse on impulse control compared with baseline testing. $^{**}P < 0.05$. (The color version of this figure is available in the online edition.)

Among individuals older than 13 years, the gender differences in the total symptom scores and cognitive function remained. Interestingly, among individuals older than 13 years, there are gender differences in impulse control ($F(1,560) = 3.62$, $P = 0.05$), such that males perform impulse control-related errors when performing the testing compared with females.

Discussion and conclusions

The objective of this research was to examine and identify any differences in concussion between males and females. The results of this study cohort demonstrate that males and females do indeed have differences in the incidence of, experience of, and recovery from a concussion. Females are more likely to be seen in the clinic with a concussion and more likely to experience more discomfort from a concussion. Similar to the available literature, headaches were the major symptom involved in the total symptomatology of concussions.[13,25-28] We found that

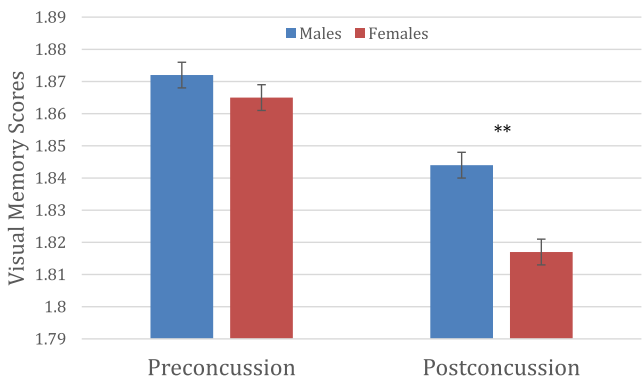

FIGURE 4.
Females perform significantly worse on visual memory testing than males after a concussion. $^{**}P < 0.001$. (The color version of this figure is available in the online edition.)

females are also more likely to seek out treatment for postconcussive headaches after sustaining a concussion.

In our data, males were most likely to be concussed from football, whereas females were most likely to present concussed from cheerleading. Interestingly, males are more likely to experience loss of consciousness, confusion, and amnesia for events surrounding the concussion than their female counterparts, which may be, in part, because males are more likely than females to sustain a concussion from a contact sport than from a noncontact sport. Similar to the documented literature, we found that loss of consciousness, although relatively rare (8% to 19%[13,15,16]), may have a higher impact on concussion symptomatology and recovery than other similar periconcussive events.

This study also examined whether neuropsychological assessment following a concussion showed gender differences. Our results indicate that both males and females exhibit differences in cognitive functioning after a concussion, particularly in visual memory, verbal memory, and impulse control testing. The cognitive testing shows that visual memory is more significantly affected in females after a concussion. A strong effort was made to ensure that we controlled for many baseline disorders that may affect neuropsychological testing such as attention deficit hyperactivity disorder, learning disabilities, and mental health concerns.

Overall, our data support the existing literature on gender differences in concussion.[6,7,9,17,19] Previous literature has found differences in performance between female and male college athletes,[20] such that female concussed college students performed worse on visual memory tasks compared with male concussed college students, which our data corroborate. Furthermore, others have shown that females have more intense consequences after suffering a concussion compared with their male counterparts, similar to our findings.[6,7,21,22] All these differences are clinically significant, as the participants were symptomatic and given the data on potential future tauopathies after sustaining concussions, these relatively small differences may have an even more significant impact in the long term. The reasons for this gender difference remain unclear; however, an increased susceptibility to concussion and hormonal differences have been proposed as possible explanations.[6,8,17]

In an effort to further understand these gender differences, we assessed for gender differences in individuals 13 years and younger. Interestingly, there were no significant gender differences in individuals 13 years and younger. This finding buttresses the current pervasive theory that hormones may play a role in gender differences in concussions.[6,8,17] Based on the increasing evidence of gender differences associated with postconcussive syndrome, further investigation is warranted.

It would have been of interest to evaluate all individuals who presented in clinic with suspected concussion and compare those with true concussions versus those with no concussion; however, those who had no concussion upon evaluation by the physician did not undergo further testing.

The implications of our findings presented here indicate that females may be at greater risk for the detrimental side effects that accompany concussion and may experience worse outcomes.[7,18] The reasons for this remain unclear. This evidence indicates that health care providers would benefit from increased awareness of the detrimental effects of concussion injury and longer recovery in females to facilitate timely intervention and treatment.[7,19] This knowledge could also help with return to school or work planning, and later return to play planning, as they progress in their recovery.

The authors thank the participants for their time and assistance in this research project.

References

1. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F. Sports- and recreation-related concussions in US youth. *Pediatrics*. 2016;138. pii:e20154635.
2. Non-fatal traumatic brain injuries from sports and recreation activities – United States, 2001-2005. *MMWR Morb Mortal Wkly Rep*. 2007;56:733-737.
3. Moser RS. The growing public health concern of sports concussion: the new psychology practice frontier. *Prof Psychol Res Pr*. 2007;38: 699-704.
4. Coronado VG, McGuire LC, Sarmiento K, et al. Trends in traumatic brain injury in the US and the public health response: 1995–2009. *J Safety Res*. 2012;43:299-307.
5. Wiebe DJ, Comstock RD, Nance ML. Concussion research: a public health priority. *Inj Prev*. 2011;17:69-70.
6. Covassin T, Elbin RJ. The female athlete: the role of gender in the assessment and management of sport-related concussion. *Clin Sports Med*. 2011;30:125-131.
7. Covassin T, Swanik CB, Sachs ML. Sex differences and the incidence of concussions among collegiate athletes. *J Athl Train*. 2003;38:238-244.
8. Broshek DK, Kaushik T, Freeman JR, et al. Sex differences in outcome following sports-related concussion. *J Neurosurg*. 2005;102: 856-863.
9. Covassin T, Swanik CB, Sachs M, et al. Sex differences in baseline neuropsychological function and concussion symptoms of collegiate athletes. *Br J Sports Med*. 2006;40:923-927.
10. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. *J Athl Train*. 2007;42:495-503.
11. Iverson GL, Lovell MR, Collins MW. Interpreting change on ImPACT following sport concussion. *Clin Neuropsychol*. 2003;17: 460-467.
12. Schatz P, Pardini JE, Lovell MR, Collins MW, Podell K. Sensitivity and specificity of the ImPACT Test Battery for concussion in athletes. *Arch Clin Neuropsychol*. 2006;21:91-99.
13. Rose SC, Weber KD, Collen JB, Heyer GL. The diagnosis and management of concussion in children and adolescents. *Pediatr Neurol*. 2015;53:108-118.
14. Iverson GL, Lovell MR, Collins MW. Validity of ImPACT for measuring processing speed following sports-related concussion. *J Clin Exp Neuropsychol*. 2005;27:683-689.
15. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clin J Sport Med*. 2003;13: 222-229.
16. Schulz MR, Marshall SW, Mueller FO, et al. Incidence and risk factors for concussion in high school athletes, North Carolina, 1996-1999. *Am J Epidemiol*. 2004;160:937-944.
17. Preiss-Farzanegan SJ, Chapman B, Wong TM, Wu J, Bazarian JJ. The relationship between gender and post concussion symptoms after sport-related mild traumatic brain injury. *PM R*. 2009;1:245-253.
18. Powell JW, Barber-Foss KD. Traumatic brain injury in high school athletes. *JAMA*. 1999;282:958-963.
19. Berz K, Divine J, Foss KB, et al. Sex-specific differences in the severity of symptoms and recovery rate following sports-related concussion in young athletes. *Phys Sportsmed*. 2013;41:58-63.
20. Covassin T, Schatz P, Swanik CB. Sex differences in neuropsychological function and post-concussion symptoms of concussed collegiate athletes. *Neurosurgery*. 2007;61:345-351.

21. Benedict PA, Baner NV, Harrold GK, et al. Gender and age predict outcomes of cognitive, balance and vision testing in a multidisciplinary concussion center. *J Neurol Sci*. 2015;353:111-115.
22. Bazarian JJ, Blyth B, Mookerjee S, He H, McDermott MP. Sex differences in outcome after mild traumatic brain injury. *J Neurotrauma*. 2010;27:527-539.
23. Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Norris JB, Hinton RY. Trends in concussion incidence in high school sports: a prospective 11-year study. *Am J Sports Med*. 2011;39:958-963.
24. Marar M, McIlvain NM, Fields SK, Comstock RD. Epidemiology of concussions among United States high school athletes in 20 sports. *Am J Sports Med*. 2012;40:747-755.
25. Eisenberg MA, Meehan III WP, Mannix R. Duration and course of post-concussive symptoms. *Pediatrics*. 2014;133:999-1006.
26. Grubenhoff JA, Kirkwood MW, Deakyne S, Wathen J. Detailed concussion symptom analysis in a paediatric ED population. *Brain Inj*. 2011;25:943-949.
27. Lee YM, Odom MJ, Zuckerman SL, Solomon GS, Sills AK. Does age affect symptom recovery after sports-related concussion? A study of high school and college athletes. *J Neurosurg Pediatr*. 2013;12:537-544.
28. Meehan III WP, d'Hemecourt P, Comstock RD. High school concussions in the 2008-2009 academic year: mechanism, symptoms, and management. *Am J Sports Med*. 2010;38:2405-2409.

Children will still die unjustly even in a perfect society. Even by his greatest effort, man can only propose to diminish, arithmetically, the sufferings of the world.

Albert Camus