Cranial Strain Patterns Associated With Concussions

Lauren Schwartzberg, OMS IV; Lilit Aslanyan, DO; Nicole Angelo, DO; Jayme Mancini, DO, PhD; Patricia S. Kooyman, DO; Reem Abu-Sbaih, DO; Hallie Zwibel, DO; Sheldon C. Yao, DO

From the Departments of Osteopathic Manipulative Medicine (Drs Mancini, Kooyman, Abu-Sbaih, and Yao) and Family Medicine (Dr Zwibel) at New York Institute of Technology College of Osteopathic Medicine (Student Doctor Schwartzberg and Drs Aslanyan and Angelo) in Old Westbury.

Financial disclosures: None reported.

Support: None reported.

Address correspondence to Sheldon C. Yao, DO, New York Institute of Technology College of Osteopathic Medicine, Department of Osteopathic Manipulative Medicine, PO Box 8000 Northern Blvd, Serota Building Room 127, Old Westbury, NY 11568-8000.

Email: syao@nyit.edu

Submitted December 14, 2018; final revision received August 30, 2019; accepted November 15, 2019.

Context: Concussions can cause cognitive impairment, somatic symptoms, and behavioral changes. Symptoms may vary in severity, depending on the degree of traumatic force. Due to the biomechanical nature of this trauma, cranial somatic dysfunctions may commonly be seen in patients with concussion.

Objective: To determine whether patients were more likely to have nonphysiologic cranial somatic dysfunctions than physiologic cranial somatic dysfunctions after sustaining a concussion.

Methods: College athletes who had a concussion based on the Immediate Post-Concussion Assessment and Cognitive test were evaluated by a physician within 1 week of the injury. Patients were evaluated for somatic dysfunctions of the cranium. Cranial somatic dysfunctions were documented; test scores and force vectors were compared with the type of strain pattern using SPSS, with $P<.05$ demonstrating statistical significance.

Results: Sixteen patients were included in the study: 10 with nonphysiologic cranial strain somatic dysfunctions and 6 with physiologic dysfunctions. Compared with lateral forces, forces of impact with anterioposterior vectors were associated 1.5 times more often with nonphysiologic rather than physiologic cranial somatic dysfunctions (P=.697). An analysis of specific cranial strain patterns and impact force vectors showed no statistical significance (P=.096).

Conclusion: There was no statistically significant association showing that concussion patients were more likely to have nonphysiologic cranial somatic dysfunctions compared with physiological cranial somatic dysfunctions. However, nonphysiologic cranial somatic dysfunctions did show a trend toward association with concussion. Further studies are needed to better understand the potential association between concussion and cranial somatic dysfunctions.

J Am Osteopath Assoc. 2020;120(9):601-606. Published online August 6, 2020.
doi:10.7556/jaoa.2020.098

Keywords: athlete, college sports, concussion, cranial strain, somatic dysfunction

Concussions are traumatic brain injuries that result from a sudden strike of forces to the cranium.[1] Both acute structural damage and subsequent molecular inflammation can result from concussions.[1,2] Approximately 5.3 million people in the United States are impaired in daily living due to transient or long-term neurologic deficits from concussions.[3-5] Concussed athletes who continue to participate in sports have prolonged recovery times and more severe symptoms. Patients with a delayed concussion diagnosis have reported significantly increased symptom severity than patients who received a diagnosis and treatment more emergently.[6] Thus, prompt evaluation of head injuries is important.

Diagnosis of a concussion involves an assessment of clinical symptoms and a physical examination. The clinical portion of the examination generally uses an objective and standardized rating tool such as the Immediate Post-Concussion Assessment and Cognitive test (ImPACT) to assess behavioral, cognitive, and sleep pattern changes sustained by an athlete after concussion.[1,3,6,7] ImPACT also measures changes in visual memory, verbal memory, processing speed, and reaction time. It is administered to athletes during a preparticipation sports physical to establish a baseline and again after the athlete has sustained a concussion. When used before and after injury in college athletes and compared with normalized demographics, ImPACT had a sensitivity of 81.9% and a specificity of 89.4% in detecting concussion-related impairment in the neurologic functions tested.[5,8]

Concussions are associated with impact forces that are responsible for inducing translation and rotation of the brain tissue, as well as stretching central nervous system fiber tracts.[9] The mean (SD) linear acceleration detected during concussions in collegiate athletes through sensing helmets was reported as 22.25g (1.79).[9] Intracranial fluid compartments (brain ventricles, vasculature, and meninges) have also been found to be distorted during concussions.[10] Although high-magnitude or repetitive forces to the head induce readily observable deformations of the skull, studies in patients with mild and moderate concussion hav also shown cranial somatic dysfunctions.[11-13]

Common concussion management includes rest and palliative symptom care, such as ibuprofen and sumatriptan.[1,3,6,7] At least 1 previous study evaluating this management approach indicated marginal benefit.[14] Other studies, including 1 from our study group, have demonstrated that osteopathic manipulative treatment (OMT) techniques can improve symptoms of vertigo, imbalance, pain, and sleep pattern disorders in patients with or without concussion.[2,11-13,15,16] One concussion case study[13] in which OMT was applied for 6 weeks resulted in the patient returning to baseline cognitive ability. Another concussion case study[11] found a reduction in impaired balance symptoms and a 6-point improvement in balance measures performed on a sensory organization test from before to after OMT. Treatment with techniques like balanced membranous tension, osteopathic cranial manipulative medicine, and myofascial release has been suggested to decrease imbalance and vertigo symptoms.[2,11-13,15] An appropriate treatment plan for patients with concussion requires a physical examination, including palpation of the head for signs of trauma, neurologic deficits, and somatic dysfunctions. In addition, osteopathic structural examinations can reveal potential cranial somatic dysfunctions after concussion.

Examining the cranium for somatic dysfunctions typically involves assessing sphenobasilar synchondrosis (SBS) biomechanics. Physiologic SBS somatic dysfunctions include sidebending rotation (SBR) or torsion patterns. Physiologic cranial somatic dysfunctions are common and can happen organically. Sidebending of SBS somatic dysfunctions occurs around 2 vertical axes with rotation around an anteroposterior axis. Torsion occurs around an anteroposterior axis as well. Conversely, nonphysiologic SBS somatic dysfunctions include vertical or lateral shears and/or compression patterns, which are less common. Lateral shears occur around 2 vertical axes, whereas vertical shears occur around 2 transverse axes. Research suggests that nonphysiologic somatic dysfunctions typically result from physical trauma and rarely resolve on their own.[17,18] Thus, identifying somatic dysfunctions of the cranium would help clinical decision-making for the integration of OMT into concussion management. The further classification of cranial somatic dysfunctions as either physiologic or nonphysiologic is useful in understanding whether the impact of the concussion likely induces a shearing or compression of the SBS. The current study aimed to determine the types of cranial somatic dysfunctions present after a concussion and whether there is an association with ImPACT scoring.

Methods

Patients

Student athletes from New York Institute of Technology (NYIT) and Long Island University (LIU) who presented to the NYIT Sports Medicine Program with a concussion between November 24, 2015, and January 30, 2018, and who were evaluated by either a family medicine physician (H.Z.) or neurologist were eligible to participate in the study. After a diagnosis of concussion was made, the physician asked the patient if he or she wanted to participate in the study. The NYIT institutional review board approved this study.

Patients were excluded if they had previous diagnoses of concussions, neurodegenerative conditions, spinal cord injuries, seizures, intractable vomiting, paralysis, or any absolute contraindications to OMT at the time of the inciting injury.

Research Design

Eligible, consenting patients completed ImPACT during the first visit (postconcussion); they also consented to providing their preparticipation sports physical (baseline) ImPACT scores. Patients provided a history describing the concussion and past medical information. They answered a questionnaire, which included demographics, date of concussion, and mechanism and force vector. Patients receiving OMT were examined while lying supine by 1 (or 2, when feasible) of 4 physicians (P.S.K., R.A.S., J.D.M. and S.C.Y.) board-certified in neuromusculoskeletal medicine and osteopathic manipulative medicine. The vault hold was used to determine the most predominant SBS somatic dysfunction. Outcome measures were differences in ImPACT scores from baseline to postconcussion.

Statistical Analysis

Normative ImPACT data ranges for above-average, average, and below-average for each category (visual memory, verbal memory, processing speed, and reaction time) were used to determine whether patients had a new-onset impairment compared with their pre-ImPACT scores.[5] Nominal values for SBS somatic dysfunction patterns and nonphysiologic or physiologic parameters were compared with the directions of impact for correlations, as well as with the presence of new-onset impairment in ImPACT scores. The directions of impact included front of head, back of head, left and right sides of face, and left and right temporal forces. Φ correlation coefficients were computed for correlations between categorical binary variables, and point-biserial correlation coefficients were computed for the correlations with age using SPSS version 24.0 (IBM), with $P<.05$, demonstrating statistical significance.

Results

Of 55 patients who presented with a head injury, 22 were not eligible or declined to participate. Of those who consented to participate, concussion was diagnosed in 16 participants. Patient ages ranged from 18 to 26 years. The study included 10 men (62.5%) and 6 women (37.5%). On physical examination, 11 patients (69%) had nonphysiologic SBS somatic dysfunctions, 9 of which were lateral somatic dysfunctions. Patients were 1.67 times more likely to have a nonphysiologic SBS cranial somatic dysfunction (P=.442). New-onset impairment (below average) from pre- to postconcussion ImPACT scores was found in 3 physiologic (60%) and 8 nonphysiologic (73%) somatic dysfunctions (**Table 1**). Those with nonphysiologic somatic dysfunctions had new-onset impairments in a mean of 2.13 out of the 4 ImPACT categories, compared with 1.2 in physiologic somatic dysfunctions. Mean changes for verbal memory in physiologic somatic dysfunctions were 22 points worse for right torsions than SBRs. Mean changes in category scales were not significant. Visual memory score changes were −4.2 for physiologic and −21 for nonphysiologic somatic dysfunctions (P=.237). Mean changes for processing speed were −4.17 for physiologic and −7.25 for nonphysiologic strains. Mean changes for reaction time were 0.01 for physiologic and −0.11 for nonphysiologic somatic dysfunctions (P=.162). There were a total of 5 physiologic cranial somatic dysfunctions, 3 SBR

Table 1.
Number of Patients With New-Onset Impairment on ImPACT Scores After Concussion (N=16)

	Visual memory	Verbal memory	Visuomotor processing speed	Reaction time
Nonphysiologic				
Lateral left (n=6)	2	3	2	3
Lateral right (n=3)	1	2	0	1
Vertical inferior (n=2)	1	0	2	0
Vertical superior (n=0)	0	0	0	0
Physiologic				
SBR (n=3)	0	1	0	0
Torsion (n=2)	1	1	2	0
Impact				
Frontal (n=8)	3	6	3	4
Occipital (n=4)	2	0	3	1
Temporal (n=3)	0	1	0	0

Abbreviations: SBR, side-bending rotation.

somatic dysfunctions, and 2 torsion somatic dysfunctions. Of samples with the same direction of impact, impact onto the back of the head (n=4) was correlated with vertical SBS somatic dysfunctions (Φ correlation coefficient=.655; n=2; *P*=.006) and negatively correlated with strains around the vertical axis (Φ correlation coefficient=−.667; n=12; *P*=.005). Otherwise, concussive impacts to similar parts of the head (n<3) were not substantial within the limited sample size (Table 2).

Discussion

Comparing the ImPACT scores before and after concussion demonstrated new cognitive impairments, likely resulting from the concussion. The nonphysiologic somatic dysfunctions were 80% lateral strains, where the sphenoid and occiput rotated in the same direction around parallel vertical axes. There were more new-onset cognitive impairments in patients with lateral and nonphysiologic somatic dysfunctions than physiologic somatic dysfunctions.

The results did not show statistical significance; however, a 69% prevalence of nonphysiologic SBS somatic dysfunctions was observed in patients. No statistically significant difference was found when comparing the vector of impact with the type or direction of cranial somatic dysfunction diagnosed after concussion. However, nonphysiologic SBS somatic dysfunctions were seen more often with anterior-posterior vectors of impact than with left-right forces.

Although the exact vector of impact forces may help explain the mechanism of injury, 1 limitation is that the variability within our small sample size was too great to characterize consistent somatic dysfunction patterns. Impact to the forehead (n=5) negatively correlated with female gender (Φ correlation coefficient=−0.522; n=6; *P*=.038), which may have been coincidence or related to a specific sport. Expanding the sample size in future studies may lead to more conclusive results and consistency among diagnoses.

A second limitation is that this population could have had other traumatic forces from previous injuries,

Table 2.
Correlation of Concussion Direction of Impact and Sphenobasilar Osteopathic Somatic Dysfunction Diagnosis, (N=16)

Direction of impact	Physiologic (n=5)	Vertical (n=2)	Lateral (n=9)	SBR (n=3)	Torsion (n=2)	Vertical (n=12)	Horizontal (n=2)	Anteroposterior (n=2)
Forehead (n=5)	−0.164 (0.545)	−0.255 (0.341)	0.323 (0.223)	−0.324 (0.221)	0.153 (0.572)	0.078 (0.774)	−0.255 (0.341)	0.153 (0.572)
Face (n=3)	0.022 (0.937)	−0.182 (0.501)	0.101 (0.710)	0.179 (0.506)	−0.182 (0.501)	0.277 (0.298)	−0.182 (0.501)	−0.182 (0.501)
Back (n=4)	−0.078 (0.774)	.655 (0.006)	−0.364 (0.166)	−0.277 (0.298)	0.218 (0.417)	−0.667 (0.005)	.655 (0.006)	0.218 (0.417)
Left temporal (n=2)	−0.255 (0.341)	−0.143 (0.598)	0.333 (0.207)	−0.182 (0.501)	−0.143 (0.598)	0.218 (0.417)	−0.143 (0.598)	−0.143 (0.598)
Right temporal (n=1)	0.383 (0.143)	−0.098 (0.719)	−0.293 (0.271)	.537 (0.032)	−0.098 (0.719)	0.149 (0.582)	−0.098 (0.719)	−0.098 (0.719)
Multiple (n=1)	0.383 (0.143)	−0.098 (0.719)	−0.293 (0.271)	.537 (0.032)	−0.098 (0.719)	0.149 (0.582)	−0.098 (0.719)	−0.098 (0.719)

Data are given a correlation (*P* value).

leading to nonphysiologic cranial somatic dysfunctions.[17,18] Treating patients with nonphysiologic cranial somatic dysfunctions after concussion could potentially decrease the severity of symptoms, although future studies that include documenting SBS somatic dysfunctions during the preseason sports physical are necessary. The subjects in another study by our author group demonstrated immediate improvement of concussion symptoms severity after OMT to address somatic dysfunctions throughout the body and not just the cranium.[19] Further studies are needed to establish presence of cranial somatic dysfunctions and severity before and after concussions and the efficacy of OMM treatment. Timely diagnosis and treatment of cranial somatic dysfunctions in patients with concussion may beneficially augment clinical outcomes.[20]

A third limitation is that only mild concussion in college athletes was studied. Recruitment of additional participants or inclusion of more chronic and severe concussions from a wider variety of traumatic events could show more compressions and other nonphysiologic somatic dysfunctions. In addition, only 1 of the 4 physicians performed the SBS examination on a given patient, limiting the study reliability. More physicians and patients could lead to more conclusive results.

Conclusion

Concussions are a common occurrence in college athletes, and treatment options are limited. Integration of OMT to treat cranial somatic dysfunctions can potentially help manage postconcussion symptoms. Although this study was limited by a small sample size, it demonstrated a potential increase in nonphysiologic SBS somatic dysfunctions and in new-onset cognitive impairments in those with nonphysiologic somatic dysfunctions. Additional studies investigating pre- and postconcussion cranial somatic dysfunctions will improve future integration of OMT into the treatment of patients with concussion. Future studies should also examine the relationships between sport type, vector force, ImPACT scores, and resulting cranial somatic dysfunctions.

Author Contributions

All authors provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;

all authors drafted the article or revised it critically for important intellectual content; all authors gave final approval of the version of the article to be published; and all authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Moy S. Concussion in athletes: from pathophysiology to current guidelines and recommendations. *Osteopath Fam Phys* 2014;2:8-13. doi:10.1016/j.osfp.2013.05.003
2. Hitscherich K, Smith K, Cuoco JA, et al. The glymphatic-lymphatic continuum: opportunities for osteopathic manipulative medicine. *J Am Osteopath Assoc.* 2016;116:170-177. doi:10.7556/jaoa.2016.033
3. National Institute of Neurological Disorders and Stroke. *Traumatic Brain Injury: Hope Through Research*. National Institutes of Health; 2002 Feb. NIH Publication No. 02-158.
4. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;21(5):375-378. doi:10.1097/00001199-200609000-00001
5. Iverson GL. *Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) Normative Data Version 2.0.* University of British Columbia & Riverview Hospital; 2003.
6. Asken BM, McCrea MA, Clugston JR, Snyder AR, Houck ZM, Bauer RM. “Playing through it”: delayed reporting and removal from athletic activity after concussion predicts prolonged recovery. *J Athl Train*. 2016;51(4):329-335. doi:10.4085/1062-6050-51.5.02
7. Brolinson PG. Management of sport-related concussion: a review. *Clin J Sport Med.* 2014;24(1):89-90. doi:10.1097/JSM.0000000000000062
8. 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(1):91–99. doi:10.1016/j.acn.2005.08.001
9. Broglio SP, Sosnoff JJ, Shin SH, He X, Alcaraz C, Zimmerman J. Head impacts during high school football: a biomechanical assessment. *J Athl Train*. 2009;44(4):342–349. doi:10.4085/1062-6050-44.4.342
10. Post A, Hoshizaki TB, Zemek R, Gilchrist MD, et al. Pediatric concussion: biomechanical differences between outcomes of transient and persistent (>4 weeks) postconcussion symptoms. *J Neurosurg Pediatr*. 2017;19(6):641-651. doi:10.3171/2016.11.PEDS16383
11. Guernsey DT III, Leder A, Yao S. Resolution of concussion symptoms after osteopathic manipulative treatment: a case report. *J Am Osteopath Assoc* 2016;116:e13-e17. doi:10.7556/jaoa.2016.036
12. Chappell C, Dodge E, Dogbey GY. Assessing the immediate effect of osteopathic manipulation on sports related concussion symptoms. *Osteopath Fam Phys*. 2015;7(4):30-35.
13. Castillo I, Wolf K, Rakowsky A. Concussions and osteopathic manipulative treatment: an adolescent case presentation. *J Am Osteopath Assoc*. 2016;116(3):178-181. doi:10.7556/jaoa.2016.034
14. Schneider KJ, Iverson GL, Emery CA, McCrory P, Herring SA, Meeuwisse WH. The effects of rest and treatment following sport-related concussion: a systematic review of the literature. *Br J Sports Med*. 2013;47(5):304-307. doi:10.1136/bjsports-2013-092190
15. Jäkel A, von Hauenschild P. Therapeutic effects of cranial osteopathic manipulative medicine: a systematic review. *J Am Osteopath Assoc*. 2011;111(12):685-693.
16. Mazzeo S, Silverberg C, Oommen T, et al. Effects of osteopathic manipulative treatment on sleep quality in student athletes after concussion: a pilot study. *J Am Osteopath Assoc*. 2020;120(9): In Press. doi:10.7556/jaoa.2020.100
17. Timoshkin EM, Sandhouse M. Retrospective study of cranial strain pattern prevalence in a healthy population. *J Am Osteopath Assoc*. 2008;108(11):652–656.
18. Pizzolorusso G, Cerritelli F, D’Orazio M, et al. Osteopathic evaluation of somatic dysfunction and craniosacral strain pattern among preterm and term newborns. *J Am Osteopath Assoc*. 2013;113(6):462-467.
19. Yao YC, Zwibel H, Angelo N, Leder A, Mancini J. Effectiveness of osteopathic manipulative medicine vs concussion education in treating student athletes with acute concussion symptoms. *J Am Osteopath Assoc*. 2020;120(9): In Press. doi:10.7556/jaoa.2020.099
20. McCallister A, Brown C, Smith M, Ettlinger H, Baltazar GA. Osteopathic manipulative treatment for somatic dysfunction after acute severe traumatic brain injury. *J Am Osteopath Assoc*. 2016;116(12):810-815. doi:10.7556/jaoa.2016.157