

PHYSICAL THERAPY MANAGEMENT OF CONCUSSION

**Physical Therapy
Evaluation of Concussion**

Independent Study Course 28.1.2

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CONTINUING PHYSICAL THERAPY EDUCATION

REFERENCES

1. American Physical Therapy Association. The physical therapist's role in management of the person with concussion. www.apta.org/uploadedFiles/APTAorg/About_Us/Policies/Practice/ManagementConcussion.pdf. Accessed August 9, 2017.
2. American Physical Therapy Association. Mission statement of the APTA. www.apta.org/uploadedFiles/APTAorg/About_Us/Policies/HOD/Goals/HOD.pdf. Accessed August 9, 2017.
3. Centers for Disease Control and Prevention. Heads up to youth sports. www.cdc.gov/headsups/youthsports/index.html. Accessed August 9, 2017.
4. Meehan W 3rd, d'Hemecont P, Comstock RD. High school concussions in the 2008-2009 academic year: mechanism, symptoms, and management. *Am J Sports Med.* 2010;38(12):2405-2409. doi: 10.1177/0363546510376737. Epub 2010 Aug 17.
5. Duhaime AC, Beckwith JG, Maerlender AC, et al. Spectrum of acute clinical characteristics of diagnosed concussions in college athletes wearing instrumented helmets: clinical article. *J Neurosurg.* 2012;117(6):1092-1099. doi: 10.3171/2012.8.JNS112298. Epub 2012 Oct 2.
6. McCaffrey MA, Mihalik JP, Crowell DH, Shields EW, Guskiewicz KM. Measurement of head impacts in collegiate football players: clinical measures of concussion after high- and low-magnitude impacts. *Neurosurgery.* 2007;61(6):1236-1243; discussion 1243.
7. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med.* 2004;14(1):13-17.
8. Aubrey M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med.* 2002;12(1):6-11.
9. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport-the 5th international conference on concussion in sport, Berlin 2016. *Br J Sports Med.* 2017. pii: bjsports-2017-097699. doi: 10.1136/bjsports-2017-097699. [Epub ahead of print]
10. Elbin RJ, Sufrinko A, Schatz P, et al. Removal from play after concussion and recovery time. *Pediatrics.* 2016;138(3). pii: e20160910. doi: 10.1542/peds.2016-0910.
11. Asken B, McCrea M, Clugston J, 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. Epub 2016 Apr 25.
12. McCrea M, Kelly J, Randolph C, et al. Standardized assessment of concussion. (SAC): on site mental status evaluation of the athlete. *J Head Trauma Rehabil*. 1998;13(2):27-36.
13. McCrea M. Standardized mental status assessment of sports concussion. *Clin J Sport Med*. 2001;11(3):176-81.
14. Collins MW, Kontos AP, Reynolds E, Murawski CD, Fu FH. A comprehensive, targeted approach to the clinical care of athletes following sport-related concussion. *Knee Surg Sports Traumaol Arthrosc*. 2014;22(2):235-246. doi: 10.1007/s00167-013-2791-6. Epub 2013 Dec 12.
15. Hicks R, Fertig S, Desrocher RE, Koroshetz WJ, Pancrazio J. Neurological effects of blast injury. *J Trauma*. 2010;68(5):1257-1263. doi: 10.1097/TA.0b013e3181d8956d.
16. Hoffer M, Balaban C, Gottshall K, Balough BJ, Maddox MR, Penta JR. Blast exposure: vestibular consequences and associated characteristics. *Otol Neurotol*. 2010;31(2):232-236. doi: 10.1097/MAO.0b013e3181c993c3.
17. O'Connor KL, Peeters T, Szymanski S, Broglio SP. Individual impact magnitude vs. cumulative magnitude for estimating concussion odds. *Ann Biomed Eng*. 2017;45(8):1985-1992. doi: 10.1007/s10439-017-1843-3. Epub 2017 Apr 28.
18. Lau BC, Kontos AP, Collins MW, Mucha A, Lovell MR. Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players? *Am J Sports Med*. 2011;39(11):2311-2318. doi: 10.1177/0363546511410655. Epub 2011 Jun 28.
19. Broglio SP, Cantu RC, Gioia GA, et al. National Athletic Trainers' Association position statement: management of sport concussion. *J Athl Train*. 2014;49(2):245-265. doi: 10.4085/1062-6050-49.1.07. Epub 2014 Mar 7.
20. Shekhar C, Gupta LN, Premasagar IC, Sinha M, Kishore J. An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India). *J Emerg Trauma Shock*. 2015;8(3):131-139. doi: 10.4103/0974-2700.160700.
21. Stiell IG, Wells GA, Vandemheen K, et al. The Canadian CT head rule for patients with minor head injury. *Lancet*. 2001;357(9266):1391-1396.
22. Haydel MJ, Preston CA, Mill TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. *N Engl J Med*. 2000;343(2):100-105.
23. Kupperman N, Holmes JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet*. 2009;374(9696):1160-1170. doi: 10.1016/S0140-6736(09)61558-0. Epub 2009 Sep 14.
24. Colvin AC, Mullen J, Lovell MR, West RV, Collins MW, Groh M. The role of concussion history and gender in recovery from soccer-related concussion. *Am J Sports Med*. 2009;37(9):1699-1704. doi: 10.1177/0363546509332497. Epub 2009 May 21.
25. Covassin T, Elbin RJ, Harris W, Parker T, Kontos A. The role of age and sex in symptoms, neurocognitive performance, and postural stability in athletes after concussion. *Am J Sports Med*. 2012;40(6):1303-1312. doi: 10.1177/0363546512444554. Epub 2012 Apr 26.
26. Lannsjo M, Backheden M, Johansson U, Af Geijerstam JL, Borg J. Does head CT scan pathology predict outcome after mild traumatic brain injury? *Eur J Neurology*. 2013;20(1):124-129. doi: 10.1111/j.1468-1331.2012.03813.x. Epub 2012 Jul 20.
27. Jacobs B, Beems T, Stulemeijer M, et al. Outcome prediction in mild traumatic brain injury: age and clinical variables are stronger predictors than CT abnormalities. *J Neurotrauma*. 2010;27(4):655-668. doi: 10.1089/neu.2009.1059.
28. Mosenthal AC, Livingston DH, Lavery RF, et al. The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multi-center trial. *J Trauma*. 2004;56(5):1042-1048.
29. Zemek RL, Yeates KO. Rates of persistent postconcussive symptoms. *JAMA*. 2017;317(13):1375-1376. doi: 10.1001/jama.2017.1327.
30. Alosco ML, Fedor AF, Gunstad J. Attention deficit hyperactivity disorder as a risk factor for concussion in NCAA division-I athletes. *Brain Inj*. 2014;28(4):472-474. doi: 10.3109/02699052.2014.887145. Epub 2014 Feb 24.
31. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA*. 1999;282(10):964-970.
32. Morgan CD, Zuckerman SL, Lee YM, et al. Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study. *J Neurosurg Pediatr*. 2015;15(6):589-98. doi: 10.3171/2014.10.PEDS14356. Epub 2015 Mar 6.
33. Emery CA, Barlow KM, Brooks BL, et al. A systematic review of psychiatric, psychological, and behavioural outcomes following mild traumatic brain injury in children and adolescents. *Can J Psychiatry*. 2016;61(5):259-269. doi: 10.1177/0706743716643741.
34. Ellis MJ, Ritchie LJ, Koltek M, et al. Psychiatric outcomes after pediatric sports-related concussion. *J Neurosurg Pediatr*. 2015;16(6):709-718. doi: 10.3171/2015.5.PEDS15220. Epub 2015 Sep 11.
35. Kontos AP, Elbin RJ, Lau B, et al. Posttraumatic migraine as a predictor of recovery and cognitive impairment after sport-related concussion.

- Am J Sports Med.* 2013;41(7):1497-1504. doi: 10.1177/0363546513488751. Epub 2013 May 22.
36. Mihalik JP, Register-Mihalik J, Kerr ZY, Marshall SW, McCrea MC, Guskiewicz KM. Recovery of posttraumatic migraine characteristics in patients after mild traumatic brain injury. *Am J Sports Med.* 2013;41(7):1490-1496. doi: 10.1177/0363546513487982. Epub 2013 May 21.
37. Rouse MW, Borsting E, Hyman L, et al. Frequency of convergence insufficiency among fifth and sixth graders. The Convergence Insufficiency and Reading Study (CIRS) group. *Optom Vis Sci.* 1999;76(9):643-649.
38. Corwin DJ, Zonfrillo MR, Master CL, et al. Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. *J Pediatr.* 2014;165(6):1207-1215. doi: 10.1016/j.jpeds.2014.08.034. Epub 2014 Sep 26.
39. Management of Concussion/mTBI Working Group. VA/DoD clinical practice guideline for management of concussion/mild traumatic brain injury. *J Rehabil Res Dev.* 2009;46(6):CP1-68.
40. Colas R, Munoz P, Temprano R, Gomez C, Pascual J. Chronic daily headache with analgesic overuse: epidemiology and impact on quality of life. *Neurology.* 2004;62(8):1338-1342.
41. Katsarava A, Obermann M. Medication-overuse headaches. *Curr Opin Neurol.* 2013;26(3):276-281. doi: 10.1097/WCO.0b013e328360d596.
42. Bigal ME, Lipto RB, Tepper SJ, Rapoport AM, Sheftell FD. Primary chronic daily headache and its subtypes in adolescents and adults. *Neurology.* 2004;63(5):843-847.
43. Heyer GL, Rose SC. Which factors affect daily compliance with an internet headache diary among youth with migraine? *Clin J Pain.* 2015;31(12):1075-1079. doi: 10.1097/AJP.0000000000000208.
44. Lovell MR, Iverson GL, Collins MW, et al. Measurement of symptoms following sports-related concussion: reliability and normative data for the post-concussion scale. *Appl Neuropsychol.* 2006;13(3):166-174.
45. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead post concussion symptoms questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. *J Neurol.* 1995;242(9):587-592.
46. Pardini J, Stump J, Lovell MR, et al. The post-concussion symptom scale (PCSS): a factor analysis (abstract). *Br J Sports Med.* 2004;38:661-662.
47. Guskiewicz KM, Bruce SL, Cantu RC, et al. National Athletic Trainers' Association position statement: management of sport-related concussion. *J Athl Train.* 2004;39(3):280-297.
48. Iverson GL, Zasler ND, Lange RT. Post-concussive disorder. In: Zasler ND, Katz D, Zafonte RD (eds). *Brain Injury Medicine: Principles and Practice.* New York, NY: Demos Medical Publishing Inc; 2007:373-405.
49. Cicerone KD, Kalmar K. Persistent postconcussion syndrome: the structure of subjective complaints after mild traumatic brain injury. *J Head Trauma Rehabil.* 1995;10(3):1-17.
50. Torres DM, Galetta KM, Philips HW, et al. Sports-related concussion: anonymous survey of a collegiate cohort. *Neurol Clin Pract.* 2013;3(4):279-287.
51. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med.* 2004;14(1):13-17.
52. O'Leary S, Falla D, Elliott JM, Jull G. Muscle dysfunction in cervical spine pain: implications for assessment and management. *J Orthop Sports Phys Ther.* 2009;39(5):324-333. doi: 10.2519/jospt.2009.2872.
53. Treleaven J, Jull G, Sterling M. Dizziness and unsteadiness following whiplash injury: characteristic features and relationship with cervical joint position error. *J Rehabil Med.* 2003;35(1):36-43.
54. Li Y, Peng B. Pathogenesis, Diagnosis, and Treatment of Cervical Vertigo. *Pain Physician.* 2015;18(4):E583-E595.
55. Neumann D. *Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation.* St. Louis, MO: Mosby Elsevier; 2010.
56. Miller MB. The cervical spine: physical therapy patient management utilizing current evidence. In: Wilmarth MA, ed. ISC 21.2.6, *Current Concepts of Orthopaedic Physical Therapy.* 3rd ed. La Crosse, WI: Orthopaedic Section, APTA; 2012.
57. Schneider KJ, Meeuwisse WH, Nettel-Aguirre A, et al. Cervicovestibular rehabilitation in sport-related concussion: a randomised controlled trial. *Br J Sports Med.* 2014;48(17):1294-1298. doi: 10.1136/bjsports-2013-093267. Epub 2014 May 22.
58. Morin M, Langevin P, Fait P. Cervical spine involvement in mild traumatic brain injury: a review. *J Sports Med (Hindawi Publ Corp).* 2016;2016:1590161. doi:10.1155/2016/1590161.
59. Chen HB, Yang KH, Wang ZG. Biomechanics of whiplash injury. *Chin J Traumatol.* 2009;12(5):305-314.
60. Walton DM, Elliott JM. An integrated model of chronic whiplash-associated disorder. *J Orthop Sports Phys Ther.* 2017;47(7):462-471. doi: 10.2519/jospt.2017.7455. Epub 2017 Jun 16.
61. Treleaven J. Dizziness, unsteadiness, visual disturbances, and postural control: implications for the transition to chronic symptoms after a whiplash trauma. *Spine (Phila Pa 1976).* 2011;36(25 Suppl):S211-S217. doi: 10.1097/BRS.0b013e3182387f78.
62. Ritchie C, Hendrikz J, Kenardy J, Sterling M. Derivation of a clinical prediction rule to identify both chronic moderate/severe disability and full recovery following whiplash injury. *Pain.* 2013;154(10):2198-2206. doi: 10.1016/j.pain.2013.07.001. Epub 2013 Jul 4.

63. Sterling M, Hendrikz J, Kenardy J, et al. Assessment and validation of prognostic models for poor functional recovery 12 months after whiplash injury: a multicentre inception cohort study. *Pain*. 2012;153(8):1727-34. doi: 10.1016/j.pain.2012.05.004. Epub 2012 Jun 1.
64. Elliott JM, Noteboom JT, Flynn TW, Sterling M. Characterization of acute and chronic whiplash-associated disorders. *J Orthop Sports Phys Ther*. 2009;39(5):312-323.
65. Treleaven J. Dizziness, unsteadiness, visual disturbances, and sensorimotor control in traumatic neck pain. *J Orthop Sports Phys Ther*. 2017;47(7):492-502. doi: 10.2519/jospt.2017.7052. Epub 2017 Jun 16.
66. Childs JD, Cleland JA. Development and application of clinical prediction rules to improve decision making in physical therapist practice. *Phys Ther*. 2006;68(1):122-131.
67. Hartling L, Pickett W, Brison RJ. Derivation of a clinical decision rule for whiplash associated disorders among individuals involved in rear-end collisions. *Accid Anal Prev*. 2002;34(4):531-539.
68. Carroll LJ, Holm LW, Hogg-Johnson S, et al. Course and prognostic factors for neck pain in whiplash-associated disorders (WAD): results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. *J Manipulative Physiol Ther*. 2009;32(2 Suppl):S97-S107. doi: 10.1016/j.jmpt.2008.11.014.
69. Ritchie C, Hendrikz J, Jull G, Elliott J, Sterling M. External validation of a clinical prediction rule to predict full recovery and ongoing moderate/severe disability following acute whiplash injury. *J Orthop Sports Phys Ther*. 2015;45(4):242-250. doi: 10.2519/jospt.2015.5642.
70. Ritchie C, Sterling M. Recovery pathways and prognosis after whiplash injury. *J Orthop Sports Phys Ther*. 2016;46(10):851-861.
71. Wrisley DM, Sparto PJ, Whitney SL, Furman JM. Cervicogenic dizziness: a review of diagnosis and treatment. *J Orthop Sports Phys Ther*. 2000;30(12):755-766.
72. Ellis MJ, Leddy JJ, Willer B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidence-based classification system with directions for treatment. *Brain Inj*. 2014;29(2):238-248. doi:10.3109/02699052.2014.965207.
73. Reid SA, Rivett DA, Katekar MG, Callister R. Comparison of mulligan sustained natural apophyseal glides and maitland mobilizations for treatment of cervicogenic dizziness: a randomized controlled trial. *Phys Ther*. 2014;94(4):466-476. doi: 10.2522/ptj.20120483. Epub 2013 Dec 12.
74. Ombregt L. Headache and vertigo of a cervical origin. In: Ombregt L. *A System of Orthopaedic Medicine*, 3rd ed. London, UK: Churchill Livingstone Elsevier; 2013.
75. Choi KD, Choi JH, Kim JS, et al. Rotational vertebral artery occlusion: mechanisms and long-term outcome. *Stroke*. 2013;44(7):1817-1824. doi:10.1161/strokeaha.113.001219.
76. Hulse M. Disequilibrium caused by a functional disturbance of the upper cervical spine, clinical aspects and differential diagnosis. *Man Med*. 1983;1:18-23.
77. Sterling M, Jull G, Vicenzino B, Kenardy J, Darnell R. Development of motor system dysfunction following whiplash injury. *Pain*. 2003;103(1-2):65-73.
78. Pietrobon R, Coeytaux RR, Carey TS, Richardson WJ, DeVellis RF. Standard scales for measurement of functional outcome for cervical pain or dysfunction: a systematic review. *Spine (Phila Pa 1976)*. 2002;27(5):515-522.
79. Cleland JA, Childs JD, Whitman JM. Psychometric properties of the neck disability index and numeric pain rating scale in patients with mechanical neck pain. *Arch Phys Med Rehabil*. 2008;89(1):69-74. doi:10.1016/j.apmr.2007.08.126.
80. MacDermid JC, Walton DM, Avery S, et al. Measurement properties of the neck disability index: a systematic review. *J Orthop Sports Phys Ther*. 2009;39(5):400-417. doi: 10.2519/jospt.2009.2930.
81. Vernon HT, Mior SA. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther*. 1991;14(7):409-415.
82. Jacobson GP, Ramadan NM, Aggarwal SK, Newman CW. The Henry Ford Hospital Headache Disability Inventory (HDI). *Neurology*. 1994;44(5):837-842.
83. Jacobson GP, Ramadan NM, Norris L, Newman CW. Headache disability inventory (HDI): short-term test-retest reliability and spouse perceptions. *Headache*. 1995;35(9):534-539.
84. Cleland JA, Fritz JM, Childs JD. Psychometric properties of the Fear-Avoidance Beliefs Questionnaire and Tampa Scale of Kinesiophobia in patients with neck pain. *Am J Phys Med Rehabil*. 2008;87(2):109-117.
85. Magee DJ. *Orthopedic Physical Assessment*, 6th ed. St. Louis, MO: Elsevier Saunders; 2014.
86. Kutcher JS, Eckner JT. At-risk populations in sports-related concussion. *Curr Sports Med Rep*. 2010;9(1):16-20. doi:10.1249/jsr.0b013e3181caa89d.
87. Teodorescu, L. Anomalous head postures in strabismus and nystagmus-diagnosis and management. *Rom J Ophthalmol*. 2015;59(3):137-140.
88. Caneiro JP, O'Sullivan P, Burnett A, et al. The influence of different sitting postures on head/neck posture and muscle activity. *Man Ther*. 2010;15(1):54-60. doi:10.1016/j.math.2009.06.002.
89. Kietrys DM, Gerg MJ, Dropkin J, Gold JE. Mobile input device type, texting style and screen size influence upper extremity and trapezius muscle activity, and cervical posture while texting. *Appl Ergon*. 2015;50:98-104. doi:10.1016/j.apergo.2015.03.003.

90. Hansraj KK. Assessment of stresses in the cervical spine caused by posture and position of the head. *Surg Technol Int*. 2014;25:277-279.
91. Dall'Alba PT, Sterling MM, Treleaven JM, Edwards SL, Jull GA. Cervical range of motion discriminates between asymptomatic persons and those with whiplash. *Spine (Phila Pa 1976)*. 2001;26(19):2090-2094. doi:10.1097/00007632-200110010-00009.
92. Childs JD, Cleland JA, Elliott JM, et al. Neck Pain: Clinical practice guidelines linked to the international classification of functioning, disability, and health from the Orthopaedic Section of the American Physical Therapy Association. *J Orthop Sports Phys Ther*. 2008;38(9):A1-A34. doi:10.2519/jospt.2008.0303.
93. Cook C. Manual therapy of the thoracic spine. In: Cook C. *Orthopedic Manual Therapy: An Evidence Based Approach*, 2nd ed. Upper Saddle River, NJ: Pearson Education; 2012.
94. Eckner JT, Oh YK, Joshi MS, Richardson JK, Ashton-Miller JA. Effect of neck muscle strength and anticipatory cervical muscle activation on the kinematic response of the head to impulsive loads. *Am J Sports Med*. 2014;42(3):566-576. doi:10.1177/0363546513517869.
95. Elliott J, Jull G, Noteboom JT, Darnell R, Galloway G, Gibbon WW. Fatty infiltration in the cervical extensor muscles in persistent whiplash-associated disorders. *Spine (Phila Pa 1976)*. 2006;31(22):E847-E855. doi:10.1097/01.brs.0000240841.07050.34.
96. Elliott JM, O'Leary S, Sterling M, Hendrikz J, Pedler A, Jull G. Magnetic resonance imaging findings of fatty infiltrate in the cervical flexors in chronic whiplash. *Spine (Phila Pa 1976)*. 2010;35(9):948-954. doi:10.1097/brs.0b013e3181bb0e55.
97. Jull GA, O'Leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: the craniocervical flexion test. *J Manipulative Physiol Ther*. 2008;31(7):525-533.
98. Falla DL, Jull GA, Hodges PW. Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. *Spine (Phila Pa 1976)*. 2004;29(19):2108-2114.
99. Chiu TT, Law EY, Chiu TH. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. *J Orthop Sports Phys Ther*. 2005;35(9):567-571. doi:10.2519/jospt.2005.2055.
100. Arumugam A, Mani R, Raja K. Interrater reliability of the craniocervical flexion test in asymptomatic individuals—a cross-sectional study. *J Manipulative Physiol Ther*. 2011;34(4):247-253. doi: 10.1016/j.jmpt.2011.04.011. Epub 2011 May 4.
101. Juul T, Langberg H, Enoch F, Søgaard K. The intra-and inter-rater reliability of five clinical muscle performance tests in patients with and without neck pain. *BMC Musculo Disord*. 2013;14:339.
102. Grimmer K. Measuring the endurance capacity of the cervical short flexor muscle group. *Aust J Physiother*. 1994;40(4):251-254. doi: 10.1016/S0004-9514(14)60461-X.
103. Chen X, Treleaven J. The effect of neck torsion on joint position error in subjects with chronic neck pain. *Man Ther*. 2013;18(6):562-567. doi: 10.1016/j.math.2013.05.015. Epub 2013 Jun 26.
104. Ellis M, Leddy J, Willer B. Multi-disciplinary management of athletes with post-concussion syndrome: an evolving pathophysiological approach. *Front Neurol*. 2016;7:136. doi: 10.3389/fneur.2016.00136. eCollection 2016.
105. Broglio SP, Collins MW, Williams RM, Mucha A, Kontos AP. Current and emerging rehabilitation for concussion: a review of the evidence. *Clin Sports Med*. 2015;34(2):213-231. doi: 10.1016/j.csm.2014.12.005. Epub 2015 Jan 24.
106. Newman-Toker DE, Camargo CA Jr, Hsieh YH, Pelletier AJ, Edlow JA. Disconnect between charted vestibular diagnoses and emergency department management decisions: a cross-sectional analysis from a nationally representative sample. *Acad Emerg Med*. 2009;16(10):970-977. doi: 10.1111/j.1553-2712.2009.00523.x.
107. Whitney SL, Marchetti GF, Morris LO. Usefulness of the dizziness handicap inventory in the screening for benign paroxysmal positional vertigo. *Otol Neurotol*. 2005;26(5):1027-1033.
108. Peterson CL, Ferrara MS, Mrazik M, Piland S, Elliott R. Evaluation of neuropsychological domain scores and postural stability following cerebral concussion in sports. *Clin J Sport Med*. 2003;13(4):230-237.
109. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train*. 2001;36(3):263-273.
110. Parker TM, Osternig LR, Lee HJ, Donkelaar P, Chou LS. The effect of divided attention on gait stability following concussion. *Clin Biomech (Bristol, Avon)*. 2005;20(4):389-395. Epub 2005 Jan 28.
111. Parker TM, Osternig LR, van Donkelaar P, Chou LS. Gait stability following concussion. *Med Sci Sports Exerc*. 2006;38(6):1032-1040.
112. Fait P, Swaine B, Cantin JF, Leblond J, McFadyen BJ. Altered integrated locomotor and cognitive function in elite athletes 30 days postconcussion: a preliminary study. *J Head Trauma Rehabil*. 2013;28(4):293-301. doi: 10.1097/HTR.0b013e3182407ace.
113. Catena RD, van Donkelaar P, Chou LS. Cognitive task effects on gait stability following concussion. *Exp Brain Res*. 2007;176(1):23-31. Epub 2006 Jul 7.
114. Cohen H, Blatchly CA, Gombash LL. A study of the clinical test of sensory interaction and balance. *Phys Ther*. 1993;73(6):346-351; discussion 351-354.

115. Horn LB, Rice T, Stoskus JL, Lambert KH, Dannenbaum E, Scherer MR. Measurement characteristics and clinical utility of the clinical test of sensory interaction on balance (CTSIB) and modified CTSIB in individuals with vestibular dysfunction. *Arch Phys Med Rehabil.* 2015;96(9):1747-1748.
116. Guskiewicz KM. Balance assessment in the management of sport-related concussion. *Clin Sports Med.* 2011;30(1):89-102, ix. doi: 10.1016/j.csm.2010.09.004.
117. Iverson GL, Koehle MS. Normative data for the modified balance error scoring system in adults. *Brain Inj.* 2013;27(5):596-599. doi: 10.3109/02699052.2013.772237. Epub 2013 Mar 8.
118. Alsalaheen BA, Haines J, Yorke A, Stockdale K, Broglio SP. Reliability and concurrent validity of instrumented balance error scoring system using a portable force plate system. *Phys Sportsmed.* 2015;43(3):221-226. doi: 10.1080/00913847.2015.1040717. Epub 2015 Jun 25.
119. Pearce KL, Sufrinko A, Lau BC, Henry L, Collins MW, Kontos AP. Near point of convergence after a sport-related concussion: measurement reliability and relationship to neurocognitive impairment and symptoms. *Am J Sports Med.* 2015;43(12):3055-3061.
120. Ciuffreda KJ, Ludlam DP, Thiagarajan P, Yadav NK, Capo-Aponte J. Proposed objective visual system biomarkers for mild traumatic brain injury. *Mil Med.* 2014;179(11):1212-1217. doi: 10.7205/MILMED-D-14-00059.
121. Mucha A, Collins MW, Elbin RJ, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: preliminary findings. *Am J Sports Med.* 2014;42(10):2479-2786. doi: 10.1177/0363546514543775. Epub 2014 Aug 8.
122. Orie MK, Marutani JK, Rouse MW, DeLand PN. Reliability study of the Pierce and King-Devick saccade tests. *Am J Optom Physiol Opt.* 1986;63(6):419-424.
123. Galetta KM, Brandes LE, Maki K, et al. The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort. *J Neurol Sci.* 2011;309(1-2):34-39. doi: 10.1016/j.jns.2011.07.039. Epub 2011 Aug 16.
124. King D, Brughelli M, Hume P, Gissane C. Concussions in amateur rugby union identified with the use of a rapid visual screening tool. *J Neurol Sci.* 2013;326(1-2):59-63. doi: 10.1016/j.jns.2013.01.012. Epub 2013 Jan 29.
125. Zee DS, Jareconettasin P, Leigh RJ. Ocular stability and set-point adaptation. *Philos Trans R Soc Lond B Biol Sci.* 2017;372(1718). pii: 20160199. doi: 10.1098/rstb.2016.0199.
126. Shumway-Cook A, Woollacott M. *Motor Control: Theory and Practical Applications*. Baltimore, MD: Lippincott Williams and Wilkins; 1995.
127. Wrisley DM, Marchetti GF, Kuharsku DK, Whitney SL. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Phys Ther.* 2004;84:906-918.
128. Williams G, Robertson V, Greenwood K, Goldie P, Morris ME. The high-level mobility assessment tool (HiMat) for traumatic brain injury. Part 1: item generation. *Brain Inj.* 2005;19(11):925-932.
129. Williams GP, Robertson V, Greenwood K, Goldie P, Morris ME. The high-level mobility assessment tool (Hi-Mat) for traumatic brain injury. Part 2: content validity and discriminability. *Brain Inj.* 2005;19(10):833-843.
130. Howe JA, Inness EL, Venturini A, Williams JI, Verrier MC. The community balance and mobility scale-balance measure for individuals with traumatic brain injury. *Clin Rehabil.* 2006;20(10):885-895.
131. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture.* 2002;16(1):1-14.
132. Nasreddine Z, Phillips N, Bedrian V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc.* 2005;53(4):695-99.
133. Pangman VC, Sloan J, Guse L. An examination of psychometric properties of the mini-mental status examination and the standardized mini-mental status examination. *Appl Nurs Res.* 2000;13(4):209-213.
134. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012. *J Am Coll Surg.* 2013;216(5):e55-71. doi: 10.1016/j.jamcollsurg.2013.02.020. Epub 2013 Apr 11.
135. Barr WB. Methodologic issues in neuropsychological testing. *J Athl Train.* 2001;36(3):297-302.
136. Lovell M, Collins M, Bradley J. Return to play following sports-related concussion. *Clin Sports Med.* 2004;33(3):421-441.
137. Lucas S, Hoffman JM, Bell KR, Dikmen S. A prospective study of prevalence and characterization of headache following mild traumatic brain injury. *Cephalalgia.* 2014;34(2):93-102. doi: 10.1177/0333102413499645. Epub 2013 Aug 6.
138. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders. 2nd edition. *Cephalalgia.* 2004;24(suppl 1):9-160.
139. Marcus DA, Kaplewski C, Rudy TE, Jacob RG, Furman JM. Diagnosis of migraine vertigo: validity of a structured interview. *Med Sci Monit.* 2004;10(5):CR197-201. Epub 2004 Apr 28.
140. Giza CC, Hovda DA. The neurometabolic cascade of concussion. *J Athl Train.* 2001;36(3):228-235.

141. Borkum JM. Chronic headaches and the neurobiology of somatization. *Curr Pain Headache Rep.* 2010;14:55-61.
142. Max JE, Keatley E, Wilde EA, et al. Depression in children and adolescents in the first 6 months after traumatic brain injury. *Int J Dev Neurosci.* 2012;30(3):239-245. doi: 10.1016/j.ijdevneu.2011.12.005. Epub 2011 Dec 17.
143. Losoi H, Silverberg ND, Waljas M, et al. Recovery from mild traumatic brain injury in previously healthy adults. *J Neurotrauma.* 2016;33(8):766-776. doi: 10.1089/neu.2015.4070. Epub 2015 Dec 17.
144. Hou R, Moss-Morris R, Peveler R, Mogg K, Bradley BP, Belli A. When a minor head injury results in enduring symptoms: a prospective investigation of risk factors for postconcussion syndrome after mild traumatic brain injury. *J Neurol Neurosurg Psychiatry.* 2012;83(2):217-223. doi: 10.1136/jnnp-2011-300767. Epub 2011 Oct 25.
145. Lange RT, Iverson GL, Rose A. Depression strongly influences postconcussion symptom reporting following mild traumatic brain injury. *J Head Trauma Rehabil.* 2011;26(2):127-137. doi: 10.1097/HTR.0b013e3181e4622a.
146. Chaput G, Lajoie SP, Naismith LM, Lavigne G. Pain catastrophizing correlates with early mild traumatic brain injury outcome. *Pain Res Manag.* 2016;2016:2825856. doi: 10.1155/2016/2825856. Epub 2016 Mar 2.
147. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand.* 1983;67(6):361-370.
148. Beck AT, Ward CH, Mendelson M, Mock J, Erbaugh J. An inventory for measuring depression. *Arch Gen Psychiatry.* 1961;4:561-571.
149. Spitzer RL, Kroenke K, Williams JB, Lowe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med.* 2006;166(10):1092-1097.
150. Leddy JJ, Willer B. Use of graded exercise testing in concussion and return-to-activity management. *Curr Sports Med Rep.* 2013;12(6):370-376. doi: 10.1249/JSR.0000000000000008.
151. Froelicher VF Jr, Thompson AJ Jr, Davis G, Stewart AJ, Triewasser JH. Prediction of maximal oxygen consumption. Comparison of the Bruce and Balke treadmill protocols. *Chest.* 1975;68(3):331-336.
152. Dematteo C, Volterman KA, Breithaupt PE, Claridge EA, Adamich J, Timmons BW. Exertion testing in youth with mild traumatic brain injury/concussion. *Med Sci Sports Exerc.* 2015;47(11):2283-2290.
153. Tirsch WS, Keidel M, Siebert M, Perz S, Doktor L, Dieker HC. Nonlinear analysis of heart rate for objective assessment of cardiac autonomic dysfunction after craniocerebral trauma. *Biomed Tech (Berl).* 1998;43(3):145-148.