Significance of Concussions in Hawai'i: From Land to Sea

David X. Cifu PhD; Olivia K. Uchima MS, CCC-SLP; Alaina S. Davis PhD, CCC-SLP; Amy E. Lower MS, CCC-SLP; Jingyu L. Jin M.Sc.(A), CCC-SLP, S-LP(C); and Henry L. Lew MD, PhD, CCC-A

Abstract

Head injuries are a particular concern in Hawai'i given the large military population, the presence of many land and water sports such as football and surfing, and the lenient helmet laws for motorcycle and bicycle riders. Physical, psychological, and cognitive symptoms from single or repeated concussions can affect an individual's reentry to society and activity. Current literature indicates that repeated head injuries are associated with chronic traumatic encephalopathy (CTE) which is thought to lead to dementia. This paper reviews literature discussing causes of concussion including its incidence and prevalence in Hawai'i. Furthermore, the neurophysiological and neurobiological etiologies are discussed followed by an overview of methods for identification and management of concussion. The paper serves as information for professionals in the community such as educators, military personnel, and healthcare workers to identify risks of concussion, management of symptoms, and to connect with resources and programs available in Hawai'i.

Keywords

concussion, mild traumatic brain injury, chronic traumatic encephalopathy, service members, athletes

Introduction

Concussion is a term used synonymously with mild traumatic brain injury (mTBI) and is an injury caused by external forces to the head that disrupt the function of the brain without penetrating the skull.[1-2] Awareness of the impact of concussions has increased over the last several years as service members returned from Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) with diagnosis of mTBI.[3-6] Former and current athletes from the National Football League have also increased awareness of head injuries as more and more players recognize the impact of repeated concussions. As these issues continue to rise, other activities have been identified as "at risk" for concussion such as soccer, surfing, and mixed-martial arts. Many of these activities are popular within the state of Hawai'i. However, the literature discussing the significance of head injury in the state is limited. This paper aims to address common causes of concussions in Hawai'i, neurophysiological factors, and directions for treatment.

Causes of Concussion

Combat-Related Concussions: The state of Hawai'i is unique in that it is home to every branch of the military and represents a disparate population at increased risk for head injury. Within the United State, approximately 100,000-250,000 concussions in service members resulted from the recent Gulf Wars, and OEF/ OIF/ OND.[3-6] An estimated 7%-12% of veterans who served in OEF/OIF/OND and received VA medical care have confirmed combat-related TBIs. Seventy-five thousand out of a total of 800,000 veterans were screened and found to have sustained concussions during combat with more than half of combat-related concussions attributed to motor vehicle accidents (MVA).[3-5] Ninety-five percent of those concussions identified were mild in severity; less than 5% were moderate to severe. About 73% of veterans with symptomatic mTBI present with a concurrent mental health diagnosis. Post-traumatic stress disorder (PTSD) is the most common mental health disorder associated with mTBI.[7-8] Over 90% of these veterans either have PTSD or chronic pain disorder.[9-10] According to the 2014 census report, there is a total of 47,213 military personnel in the state of Hawai'i.[11] The Department of Defense reported that the prevalence of mTBI in the Army was 3 times higher than other branches.[12] With four active Army bases in Hawai'i, it is very likely that the military population within the state significantly contributes to these statistics. Also, the University of Hawai'i at Manoa has a large ROTC program with cadets who may have previously deployed and may have experienced combat situations with exposure to events that lead to head injury.

Motor Vehicle Accidents: The most common non-sport civilian concussions are from motor vehicle accidents (MVA). Emergency departments in the United States treated almost 2.6 million individuals for injuries after a motor vehicle collision.[13] The most recent data for nonfatal injuries secondary to MVA in 2011 reported 433 injuries per 100,000 persons in Hawai'i.[14] The Injury Prevention and Control Section of the

Abbreviations:

AD = Alzheimer's Disease
CSF = Cerebral Spinal Fluid
CTE = Chronic Traumatic Encephalopathy
DOH = Department of Health
mTBI = Mild Traumatic Brain Injury
MVA = Motor Vehicle Accidents
NFL = National Football League
NFT = Neurofibrillary Tangles
OEF = Operation Enduring Freedom
OIF = Operation Iraqi Freedom
OND = Operation New Dawn
MMA = Mixed-Martial Arts
PCE = Post-Concussive Event
PCS = Post-Concussive Symptom
PTA = Post-traumatic Amnesia
PTSD = Post-traumatic Stress Disorder
TBI = Traumatic Brain Injury
VA = Veterans Affairs

Hawai'i State Department of Health (DOH) reported that 21% of nonfatal injuries from motorcycle crashes resulted in TBI between the years 2007-2011, followed by bicycle (18%) and automobile (16%) accidents.[15] The use of airbags in vehicles has decreased TBI fatalities but has consequently increased mTBIs that may continue to impact the victims' daily living. Although motorcycles, mopeds, scooters, and bicycles are popular forms of transportation in Hawai'i the state has only enacted a law requiring helmet use among children. The law states that persons must wear a helmet when riding a bicycle if under the age of 16 years and when driving a motorcycle if under the age of 18 years.[16-17] Concussions from MVAs demonstrate elements similar to sport and combat mTBIs.[18-20]

Sports-Related Concussions: Sports-related concussions have become a significant topic of interest due to the recent attention from the media, particularly in American football from youth to professional leagues. Within the United States, there are more than 3.8 million concussions related to sports and recreational activities annually.[18] Approximately 5%-9% of all sports injuries are concussions. Football, wrestling, girl's and boys' soccer, and girls' basketball have the highest incidence of concussions.[3-4] Another unique aspect of Hawai'i is the high participation in watersports by the locals and tourists. According to the DOH,[15] an average of 9% of near drowning accidents resulted in traumatic brain injury. Woodacre, et al, found that 24% of injuries in surfers were classified as head injuries.[21] Another study by Swinney assessed the prevalence of TBI and the use of protective gear in 50 surfers.[22] Among this sample, 70% (n = 35) reported sustaining a head injury, and of those, 37.1% (n = 13) were concussions.

Athletes who sustain a sports-related concussion have a greater likelihood of experiencing repeated concussions.[23] University athletic teams involved in sports such as football and soccer are also high risk for repeated concussions during games and practice sessions. Most concussions sustained by athletes occur during practices as opposed to competitive games. In addition, women are more likely to experience concussions than men within the same sport.[24-25] Preliminary data from a pilot study at the University of Hawai'i UH that surveyed a female university soccer team in Hawai'i found that 35% of the participants (n = 20) sustained a concussion either during a game or practice.[26] Mixed-martial arts (MMA) is another popular sport in Hawai'i and is also considered high risk for repeated concussions. Ngai, Levy, and Hsu reported a rate of 15.4 severe concussions per 1000 athlete exposures.[27] An ongoing study which includes MMA competitors indicates that at least 58% of the participants (n = 12) report an average of 2.85 concussions during practice, fights, or both.[28]

Neurophysiological Aspects of Concussion

The aftermath of sustaining a concussion with loss of consciousness is commonly the result of diffuse axonal injury in which the rotational movements of the brain within the skull damages axons.[2,29] Persons who sustain a concussion experience an alteration or loss of consciousness for up to 30 minutes with associated memory loss or post-traumatic amnesia (PTA) surrounding the event. Additional neurologic sequelae may also be present, including numbness, dizziness, uncoordination, and alterations in special senses. These sequelae and PTA are typically symptomatic for up to 24 hours following the event.[4]

More recently, clinical and research professionals are attempting to increase the awareness of potentially concussive events (PCE), particularly in high-risk activities such as exposure to blasts while serving in the military and contact sports. A PCE is an impulsive force to the head that can result in acute or chronic symptoms in some individuals; while others may be asymptomatic.[3-4] According to the Veterans Administration (VA), acute post-concussive symptoms (PCS) are characterized by axonopathy, altered glucose metabolism, short-term musculoskeletal or soft-tissue pain, and psychological changes.[30] There are concerns related to the long-term effects that may be present following this potentially cumulative trauma disorder. Chronic PCS is the result of permanent damage to axons, along with noted psychological changes.[4] Additional symptoms of PCS include persistent physical symptoms such as headaches, dizziness, blurred/double vision, and insomnia. Cognitive changes include deficits in attention, executive function, short-term memory loss, and changes in social-communication skills.[31-32] Individuals with PCS may also experience emotional and psychological symptoms. Studies have shown that 80%-90% of symptoms typically resolve within 1-4 weeks of the incident.[33] However, they usually present within the first 1-2 weeks following the event and may last for at least three months in 15%-30% of individuals. It is unclear what this means in consideration of prognosis and treatment. In 5% of cases, the consequences of concussions last more than one year. While research continues to investigate the long-term effects of concussion, there is scientific evidence that single moderate-severe TBIs are associated with long-term risks. There is also evidence that, although symptoms related to concussion may have subsided after one week of rest, the brain may not have fully recovered.

Repeated concussions can predispose individuals for neurological degeneration later in life. Athletes from the National Football League (NFL) may sustain 3,000-8,000 concussions over a lifetime of sports while American combatants from the war in Iraq report 1-151 mTBIs (average of 4) during their service.[3-5] Post-mortem examinations of the brains of former NFL players have led to the identification of chronic traumatic encephalopathy (CTE).[34] CTE, also termed "Punch Drunk" or Dementia Pugilistica is a neurodegenerative disease caused by repeated head trauma and is considered to be progressive.[35] CTE begins insidiously and usually presents over many years (5-10) following the concussive event or after the patients have stopped playing sports. Inattention, mood and behavior disturbances, confusion, and memory loss are typical symptoms. A brain with CTE exhibits physiological signs such as atrophy of frontal and temporal cortices, dilation of the lateral and third ventricles, and thinning of the corpus callosum. Postmortem microscopic examinations reveal neuronal loss and tau deposition in neurons

(neurofibrillary tangles; NFTs) and astrocytes. This pathology involves the cerebral cortex (perivascular areas, deep layers), white matter, deep nuclei, and the brainstem.[36-37]

CTE may progress over many years (5 or more) to dementia and Parkinsonism. Studies have found that multiple mTBIs can further increase the likelihood of developing CTE; however further investigation through longitudinal studies is needed. Increased research suggests that even a single event of moderate to severe TBI leads to higher risk of the development of Alzheimer's Disease (AD) in the long-term.[37-39] AD is characterized neuropathologically by beta-amyloid neuritic plaques and NFTs. CTE also shows accumulation of NFTs that are similar to those of AD, and few, if any, neuritic b-amyloid plaques.[3-5] Despite the similarities and differences in the biological makeup of AD and CTE, the results present as symptoms of dementia, which can lead to a multitude of social difficulties and medical complications.

Identification and Treatment

High-quality neuroimaging technology is commonly available (eg, diffuser tensor imaging, susceptibility weighted imaging, diffusion tensor tractography, and positron emission tomography). However, it is unclear whether brain imaging should be utilized in patients with TBI for acute clinical care, long-term management prediction, or research. Despite premium neuroimaging techniques, there is currently no gold standard to allow specialists to diagnose concussions and provide a prognosis for each patient accurately. Efforts have been made to identify cerebral spinal fluid (CSF), blood, urine, and/or salivary biomarkers of TBI.[3-5,40] Consequently, acute injury markers in CSF of moderate-severe TBIs defined in rodents have fair sensitivity but poor specificity in humans. Currently, there are no clear acute or chronic biomarkers for mTBI.

Recently, there has been a move to "advance best practices, policies, and research related to the care of injured service members."[41] The VA's treatment of mTBI is called "post-deployment syndrome management" and is a three-tiered process that includes education, intervention, and goals.[4,30] Education consists of diagnosis including the explanation of multiple contributors, such as prognosis from evaluating an individual's level of optimism/self-actualization. Education also addresses health management such as levels of fitness, sleep, diet, and mind/body wellness. Interventions address maintaining adequate levels of sleep either naturally or with medication, pain management, and behavior management through counseling with the option of dosing with mood stabilizers. Cognitive rehabilitation with a certified speech-language pathologists addresses cognitive-linguistic deficits and functional life participation. The goals include normalization, deinstitutionalization, return to productivity and activity, and reintegration into social roles and activities.[4,30]

Guidelines for an athlete's return to school and play are determined based on a consensus from a multidisciplinary team who monitors the student from the moment of experiencing the concussive event. Symptom management is the primary tool, but it is undecided if there should be focal or comprehensive neuropsychological testing for incidents in this population. It is considered "best practice" for athletes to return to their sport once they are symptom-free at rest as well as during physical activity.[4,42] This means that the athlete is released to participate in regular activities after passing physical and neurological tests or screeners. However, previous literature indicate that symptom resolution and return-to-normal brain function do not appear to be simultaneous.[43]

Conclusion

It is imperative for professionals in Hawai'i to understand the activities that lead to concussions, the etiology of the injury, and how it affects the individual for appropriate identification and treatment. In consideration of return to work, school, and other life activities, there may be short- and long-term consequences in returning to premorbid activities too soon which can affect athletes, military personnel, and civilians. There are laws in place for children and adolescents. In 2012 the Hawai'i Sess. Laws Act. 197 (2012 HB 2273) was enacted and required the development of a concussion awareness program within public and private schools to provide guidelines for education, identification, and management of concussion for children and adolescents between the ages of 14-18 years. The Hawai'i Concussion Awareness Management Program provides education and baseline testing to high school students in the state.[44] Within the young adult population, the National Collegiate Association of America partnered with the Department of Defense in 2014 to study concussion and its impact.[45] Additional programs that make efforts to raise awareness of concussions in Hawai'i through programs such as the Hawai'i Neurotrauma Registry, in which individuals of all ages voluntarily provide information related to their brain injury.[46] The registry is beneficial in that it tracks the reported brain injuries in the state with the intention to support future legislative change to support increased care. Furthermore, the Department of Communication Sciences and Disorders at the University of Hawai'i is conducting research on brain injury to investigate high-risk populations in the area of cognitive-linguistic skills and audiology. Continuation of these programs will assist in the prevention and better management of brain injuries in the state by providing appropriate and adequate resources to those working with high-risk populations. Further research that investigates the long-term effects of repeated concussions is necessary as clinicians are seeing an increase in patients who have sustained TBIs.

Conflict of Interest

None of the authors identify a conflict of interest.

Authors' Affiliations:
- Department of Physical Medicine and Rehabilitation, School of Medicine, Virginia Commonwealth University,
Richmond VA; Department of Physical Medicine and Rehabilitation, Department of Veteran's Affairs, Washington, DC (DXC)
- Department of Speech Language Pathology and Swallowing, Queen's Medical Center, Honolulu, HI (OKU)
- Department of Communication Sciences and Disorders, University of Hawai'i at Manoa, Honolulu, HI (ASD, AEL, JLJ, HLL)

Correspondence to:
Alaina S. Davis PhD, CCC-SLP; University of Hawai'i, John A. Burns School of Medicine, Department of Communication Sciences and Disorders,
677 Ala Moana Blvd, Suite 625, Honolulu, HI 96815;
Ph: (808) 692-1584; Email: davisas@hawaii.edu

References

1. Payne JC, Wright-Harp W, Davis AS. Traumatic brain injury. In JC Payne *Adult neurogenic language disorders: Assessment and treatment – A comprehensive ethnobiological approach,* (2nd Ed.). 2014. Plural Publishing: San Diego, CA.
2. Timmons T, Maneker J. Traumatic brain injury in the elderly. *Clin Ger.* 2010;18:20-24.
3. Cifu DX. Concussion diagnosis and management: Playing field to battlefield. Rehabilitation Institute of Chicago TBI Conference; 2014 June 5; Chicago, Illinois.
4. Cifu DX. Battlefield to Ball Field: An integrative approach to traumatic brain injury. Hawaii Speech-Language-Hearing Association; 2015 July 12; Honolulu, Hawaii.
5. Cifu DX, Taylor BC, Carne WF, Bidelspach D, Sayer NA, Scholten J, Campbell EH. Traumatic brain injury, posttraumatic stress disorder, and pain diagnoses in OIF/OEF/OND Veterans. *J Rehab Res Dev*. 2013;50(9):1169-76.
6. Cifu DX, Hoke KW, Wetzel PA, Wares JR, Gitchel G, Carne W. Effects of hyperbaric oxygen on eye tracking abnormalities in males after mild traumatic brain injury. *J Rehab Res Dev*. 2014;51(7):1047-1055.
7. Nayback AM. Health disparities in military veterans with PTSD: Influential sociocultural factors. *J Pscyhosoc Nurs.* 2008;46(6):43-51.
8. Schneider SL, Haack L, owens J, Herrington DP, Zeek A. An interdisciplinary treatment approach for soldiers with TBI/PTSD: Issues and outcomes. *Persp Neurophys Neurogen Spch and Lang Dis.* 2009;19:36-46.
9. Carlson KF, Nelson D, Orazem RJ, Nugent S, Cifu DX, Sayer NA. Psychiatric diagnoses among Iraq and Afghanistan war veterans screened for deployment-related traumatic brain injury. *J Traum Stress.* 2010;23:17–24.
10. Taylor BC, Hagel EM, Carlson KF, Cifu DX, Cutting A, Bidelspach DE, Sayer NA. Prevalence and costs of co-occurring traumatic brain injury with and without psychiatric disturbance and pain among Afghanistan and Iraq War Veteran V.A. users. *Med Care*. 2012;50(4):342–346.
11. Huffington Post. Hawaii's military presence (Infographic). Sept 2013. Retrieved from http://www.huffingtonpost.com/2013/09/26/hawaii-military-presence_n_4000020.html.
12. Defense and Veterans Brain Injury Center. Department of Defense numbers for traumatic brain injury Worldwide numbers – Army. Dec 2015. Retrieved from http://dvbic.dcoe.mil/sites/default/files/2015-Q3-DoD-TBI-Worldwide-Totals_2015-Q1-Q3_2015-12-08.pdf.
13. Centers for Disease Control and Prevention. Injury prevention and control: Motor vehicle safety. *National Center for Injury Prevention and Control, Division of Unintentional Injury Prevention*. Jun 2012. Retrieved from http://www.cdc.gov/motorvehiclesafety/mc/states/hi.html .
14. Hawaii Health Matters. Nonfatal injuries due to motor vehicle collisions. Retrieved from http://www.hawaii healthmatters.org/modules.php?op=modload&name=NS-Indicator&file=indicator&indid=3000673000395 & iid=7826370
15. Hawaii Department of Health. Injuries in Hawaii 2007-2011. *Injury Preventions and Control Section: Hawaii State Department of Health*. 2012
16. Hawaii The 20th State Legislature. Hawaii Law. 2000. Retrieved from http://www.bhsi.org/hawaii.htm.
17. Motorcylcle Operater's Manual. Hawaii Department of Transportation. (n.d.) http://hidot.hawaii.gov/highways/ files/ 2013/01/mvso-Motorcycle-Operator-Manual.pdf
18. Langlois JA, Rutland-Brown, W, Wald, MM (2006). The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trau Rehab.* 2006;21(5):375-378.
19. Hanlon RE, Demery JA, Martinovich Z, Kelly JP. Effects of acute injury characteristics on neuropsychological status and vocational outcome following mild traumatic brain injury. *Brain Inj.* 1999;13(11):873-887.
20. Lange RT, Pancholi S, Brickell TA, Sakura S, Bhagwat A, Merritt V, French LM. Neuropsychological outcome from blast versus non-blast: mild traumatic brain injury in US military service members. *J Int Neuropsychol Soc.* 2012;18(03):595-605.
21. Woodacre T, Waydia SE, Wienand_Barnett S. Aetiology of injuries and the need for protective equipment for surfers in the UK. *Injury*. 2015;46(1):162-5.
22. Swinney, C. Assessing the prevalence of traumatic head injury amongst recreational surfers in the United States. *Hawaii J Med Public Health.* 2015;74(12):403-405.
23. Guskiewicz KM, McCrea M, Marshall SW, Cantu RC, Randolph RC, Barr W, Onate JA, Kelly JP. Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA Concussion Study. *JAMA*, 2003;290(19):2549 –2555.
24. Covassin T, Swanik CB, Sachs ML. Sex Differences and the Incidence of Concussions Among Collegiate Athletes. *J Athl Train.* 2003;38(3):238-244.
25. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives. *J Athl Train.* 2007;42(2):311-319.
26. Kolacz A, Shimazu A, Davis AS & Lew HL. Knowledge and awareness of cognitive-linguistic deficits associated with concussion in college athletes. American. Speech-Language-Hearing Association National Convention (2015 November 13), Denver, Colorado.
27. Ngai KM, Levy F, Hsu EB. Injury trends in sanctioned mixed martial arts competition: a 5-year review from 2002 to 2007 *Br J Sports Med.* 2008,42:686-689 doi:10.1136/bjsm.2007.044891
28. Hoggard E, Murata KN, Parson L, Davis AS, Lew HL. Memory, social communication, and executive function skills in mixed-martial arts competitors. American. Speech-Language-Hearing Association National Convention (2015 November 14), Denver, Colorado.
29. Guitierrez E, Huang Y, Hagid K, Bao F, Hanson HA, Hamberger A. Viano D. A new model for diffuse brain injury by relational acceleration: I model, gross appearance, and astrocytes. *J Neurotrau*. 2001;18:247-257.
30. Veteran's Affairs/Department of Defense. Management of Concussion/mTBI Working Group. VA/DoD Clinical Practice Guideline for Management of Concussion/Mild Traumatic Brain Injury. *J of Rehab Res Dev.* 2009;46(6):CP1.
31. Lew HL, Cifu DX, Crowder AT, Grimes JB. Guest editorial: Sensory and communication disorders in traumatic brain injury *J Rehab Res Dev*. 2012;*49*(7), vii-x.
32. Dennis K. Current perspectives of traumatic brain injury. *ASHA Access Aud.* 2009;8(4).
33. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003;290(19):2556–2563.
34. McKee AC, Cantu RC, Nowwinski CJ, Hedley-Whyte, ET, Gavett BE, Budson AE, Santini VE, Lee H, Kubilus C, Stern RA. Chronic traumatic encephalopathy in athletes: Progressive tauopathy after repetitive head injury. *J Neuropathol Exp Neurol.* 2009;68:709-35.
35. Omalu BI, Hamilton RL, Kamboh MI, DeKosky ST, Bailes J. Chronic traumatic encephalopathy (CTE) in a National Football League Player: Case study report and emerging medicolegal practice questions. *J For Nurs.* 2010;6:40-46.
36. McKee AC, Stein TD, Nowinski CJ, Stern RA, Daneshvar DH, Alvarez VE, Lee H, Hall G, Wojtowicz SM, Baugh CM, Riley DO, Kubilus CA, Cormier KA, Jacobs MA, Martin BR, Abraham CR, Ikezu T, Ross RR, Wolozin BL, Budson AE, Goldstein LE, Kowall NW, Cantu RC. The spectrum of disease in chronic traumatic encephalopathy. *Brain,* 2013;136:43-64.
37. Mortimer JA, van Duijn CM, Chandra V, Fratiglioni L, Graves AB, Heyman A, Jorm AF, Kokmen E, Kondo K, Rocca WA. Head trauma as a risk factor for Alzheimer's disease: a collaborative re-analysis of case–control studies. EURODEM Risk Factors Research Group. *Int J Epidemiol*, 1998;20:S28-S35.
38. Fleminger S, Oliver D, Lovestone S, Rabe-Hesketh S, Giora A. Head injury as a risk factor for Alzheimer's disease: the evidence 10 years on; a partial replication. *J Neurol Neurosurg Psychiatry.* 2003;74(7):857-862.
39. Gandy S, Ikonomovic MD, Mitsis E, Elder G, Ahlers ST, Barth J, Stone JR, DeKosky ST. Chronic traumatic encephalopathy: clinical-biomarker correlations and current concepts in pathologenesis. *Mol Neurodeg.* 2014;9(37):1-21.
40. Omalu BI, DeKosky ST, Minster RL, Kamboh MI, Hamilton RL, Wecht CH. Chronic traumatic encephalopathy in a National Football League player. *Neurosurg.* 2005;57(1):128-134.
41. Cornis-Pop M, Mashina PA, Roth CR, Maclennan DL, Picon LM, Hammond CS, Goo-Yoshino S, Isaki E, Singson M, Frank EM. Cognitive-communication rehabilitation for combat-related mild traumatic brain injury. *J Rehabil Res & Dev*. 2012;49(4):xi-xxxi.
42. McGrath N. Supporting the student-athlete's return to the classroom after a sport-related concussion. *J Athlet Train*. 2010:45(5):492-498.
43. Hugenholtz H, Stuss DT, Stethem LL, Richard MT. How long does it take to recover from a mild concussion? *Neurosurg*. 1988;22(5):853-858.
44. Hawaii Concussion Awareness Management Program. 2013. Retrieved from http://hawaiiconcussion.com/ Concussion-Information.htm.
45. National Collegiate Athletic Association. Concussion and college sports. Dec 2015 Retrieved from http://www.ncaa.org/health-and-safety/medical-conditions/concussion.
46. Pacific Disabilities Center. Hawaii neurotrauma registry project. 2014. Retrieved from http://manoa.hawaii.edu/pdc/hawaii-neurotrauma-registry-project/.