Transcranial Doppler Ultrasound for Concussion in Amateur Athletes

Work In Progress

Charles Tegeler, MD, Jongyeol Kim, MD, *Greg Collins, ATC, * Don Steelman, ATC, **Kevin Westwood, Patrick Reynolds, MD, David Martin, MD, Jason Greenberg, MD, and David Stump, PhD, Wake Forest University School of Medicine, *Wake Forest University Department of Athletics, ** Forsyth Country Day School, Winston-Salem, North Carolina

Abstract

BACKGROUND: There are 300,000 sports-related concussions (SRC) in the USA yearly. Most are mild and brief, but deficits can be severe or persistent, especially with repeat SRC. Return to play decisions (RTPD) are based on symptoms, symptom-based guidelines, or neuropsychological testing (NPSY). A mismatch in brain metabolism (increased) and blood flow (decreased) has been suggested. Response and function of cerebral vessels after SRC is poorly understood, but maybe important regarding RTPD. Transcranial Doppler ultrasound (TCD) is safe, noninvasive, and can study cerebral hemodynamics and responsiveness. This pilot study assesses TCD changes after SRC in amateur athletes. METHODS: TCD testing at rest, and with continuous bilateral MCA monitoring during hyperventilation, breath holding, and leg up tilt, a neurological exam, and computerized NPSY (ImPACT) were done at baseline and following SRC in 91 athletes at Wake forest University (82 football, 1 soccer) and Forsyth Country Day School (4 football, 4 soccer). RESULTS: Thus far, there are 8 SRC's (3 with baseline testing). NPSY showed impairment after all SRC. Initial TCD analysis shows differences in response to breath holding after SRC. CONCLUSION: This work-in-progress pilot study shows that TCD is feasible in amateur athletes at risk for SRC, and can assess cerebral hemodynamics and responsiveness. Initial results suggest differences in response to breath holding after SRC. TCD may reveal pathophysiological mechanisms of SRC, identify opportunities for acute treatments, and provide an additional objective measure to assist with return to play decisions.

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Background

Sports-related head injuries, concussions, remain a frequent and challenging medical problem in the United States, with 800 events per day, or about 300,000 per year. There is risk with any contact sport, but incidence is highest in football (4-20%/yr). The AAN has defined concussion as, “a trauma-induced alteration in mental status that may or may not involve loss of consciousness”. Clinical hallmarks are confusion and amnesia, with a myriad of other potential signs, and a multiplicity of potential symptoms including headache, dizziness/vertigo, nausea/vomiting, impaired attention/concentration, impaired memory, irritability, visual problems, anxiety, depression, or disturbed sleep. Most concussions have mild-moderate symptoms, are of brief duration, and resolve spontaneously, but there may be significant morbidity and dysfunction, and that athlete is usually held out of competition for a period of time. There is also risk of permanent brain injury, either from the initial event, from cumulative effects of repeated concussions, or due to the potentially devastating second impact syndrome. The brain is more vulnerable after concussion, and may suffer a more severe injury, possibly with a less severe trauma, if there is a repeat concussion, especially early after the initial event. The timing of when it is safe to return to play remains a dilemma.

Understanding of the pathophysiological mechanisms of concussion remain incomplete. The trauma causes axonal shearing injury in neurons, leading to altered cellular metabolism, abnormal ionic shifts of Ca+ and K+, and release of excitatory neurotransmitters. There is increased metabolic need, but apparent relatively abnormal cerebrovascular function and responsiveness, leading to a mismatch between cellular metabolic needs and the ability of the cerebral circulation to meet them.

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Background

Evaluation of athletes with concussion has improved greatly, with published criteria for assessing severity, and a Standardized Assessment of Concussion for on-field evaluation by Training Staff. Neuropsychological testing can accurately identify deficits after concussion. Computerized neuropsychological testing, such as Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), have improved ease of administration and brevity of testing (20-30 minutes). These are now widely used in the NFL and NHL to establish preseason baselines, assess function after concussion, and help make return to play decisions . Despite these advances, treatment remains conservative and symptomatic, keeping the athlete out of play until rather arbitrary time intervals, or until cognitive function has improved. Despite strong evidence for abnormal cerebral hemodynamics, function and vessel responsiveness after concussion, a safe, simple, accurate method to assess brain circulation after concussion has not been established. Knowledge of cerebrovascular function may be key to decisions about safety of return to play, improve understanding of pathophysiological mechanisms, and identify possible treatment strategies.

Transcranial Doppler ultrasonography (TCD) is a safe, noninvasive, reproducible, widely available, and clinically useful method to study the brain circulation. Evoked flow testing with TCD, most often with manipulation of CO2 with hyperventilation or breath holding, can assess cerebrovascular reserve and responsiveness. Conventional TCD testing, using mean flow velocity and various derived parameters, has some difficulty distinguishing between high velocity due to stenosis/spasm vs. increased flow. A new method for analyzing TCD data, Dynamic Vascular Assessment (DVA) has been developed to better assess cerebrovascular performance (New Health Sciences, Inc, Rockville, MD). DVA identifies the optimal waveform at each segment, measures the mean flow velocity, systolic flow acceleration, and the pulsatility index, using these data, and their interrelationships, to determine the physiological state of the vessel segment, and segments distally. This has been clinically valuable in sleep apnea, hydrocephalus, AVM, and atherosclerotic CVD, but has not been used in concussion.

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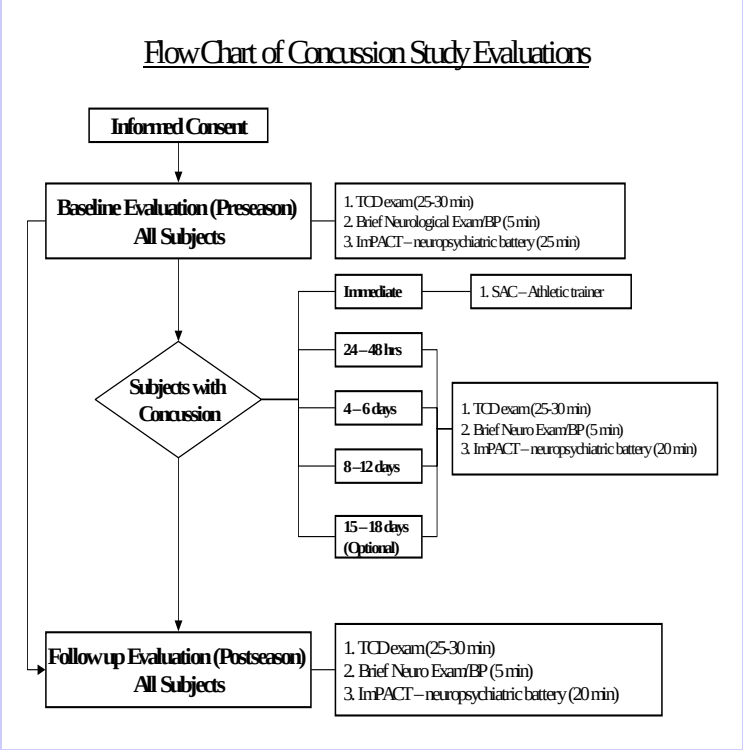
Methods/Design

Athletes were recruited from Wake Forest University and Forsyth Country Day School in Winston-Salem, NC. Athletes had a baseline evaluation including neurological examination, Blood Pressure, a TCD exam (100M TCD Instrument, Spencer Technologies, Inc, Seattle, WA), and computerized ImPACT Neuropsychological Testing (Version 2.0, University of Pittsburgh Medical Center, Pittsburgh, PA). These were repeated after concussion with targets of 24-48 hours, 4-5 days, 8-12 days, and 15-18 days (optional). Athletes who had not yet had baseline studies were serially assessed at the same time targets. TCD testing included initial measurements in the MCA, ACA, and PCA bilaterally, then bilateral monitoring (2 channel, with fixation using Spencer head frame) during a 30 second breath holding (BH), hyperventilation for 15 seconds, and a 2 minute leg-up tilt. Routine TCD parameters (Mean velocity and pulsatility) were assessed for all maneuvers. DVA has thus far been done only on those having concussion and baseline studies.



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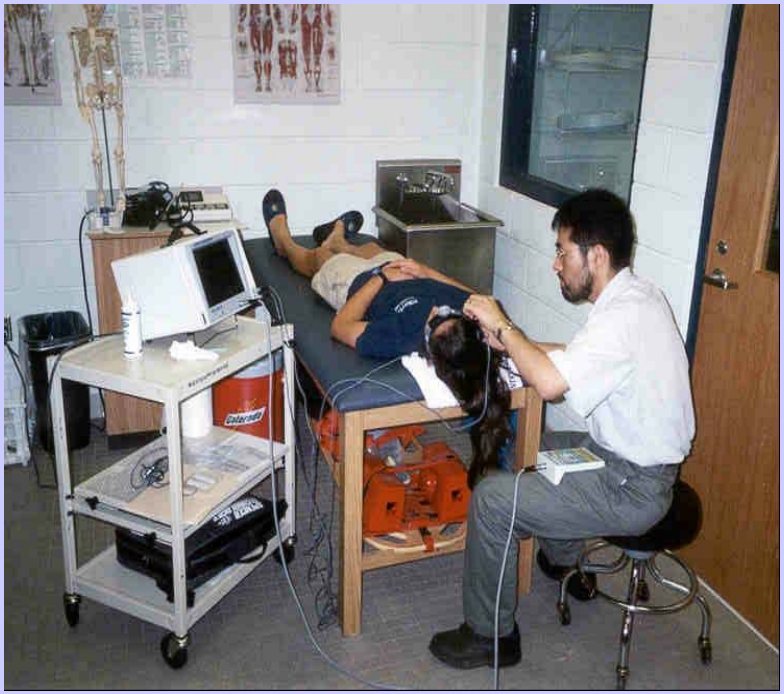

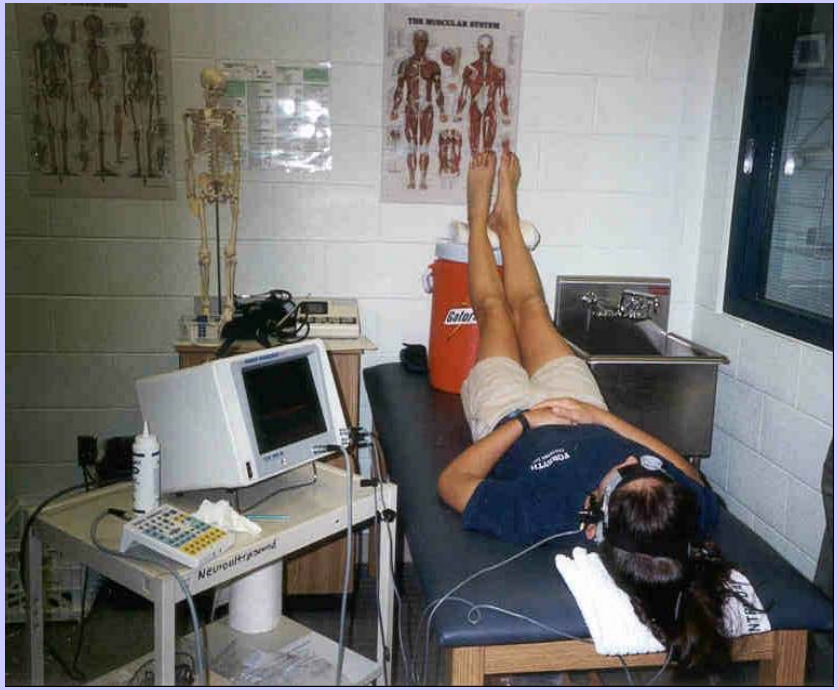

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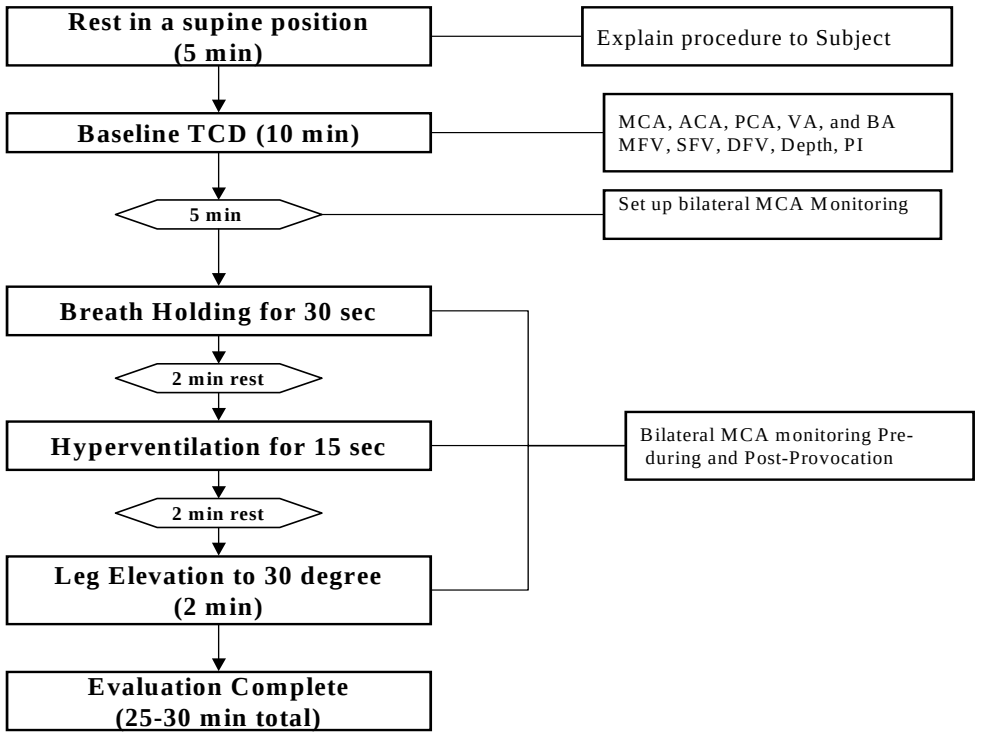
Flow Chart of TCD Examination for Concussion Study



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Interim Results

To date, there have been 91 athletes evaluated at Wake Forest University (82 football, 1 soccer), and Forsyth Country Day School (4 football, 4 soccer). There have been 8 sports-related concussions, of which 4 athletes had baseline (pre-concussion) assessments.

There are demonstrable changes in neuropsychological performance after concussion (Figure) that improve over time. There were no obvious differences in the initial routine TCD data after concussion, nor any obvious changes in response to hyperventilation or leg-up tilt. There did appear to be differences in the response to breath holding. As shown in the data from one athlete before and after concussion (Figure), there appears to be a lessened response to breath holding. There also appears to be a prolongation of the time from maximal response to return to baseline velocity. There are too few data to confirm significance.

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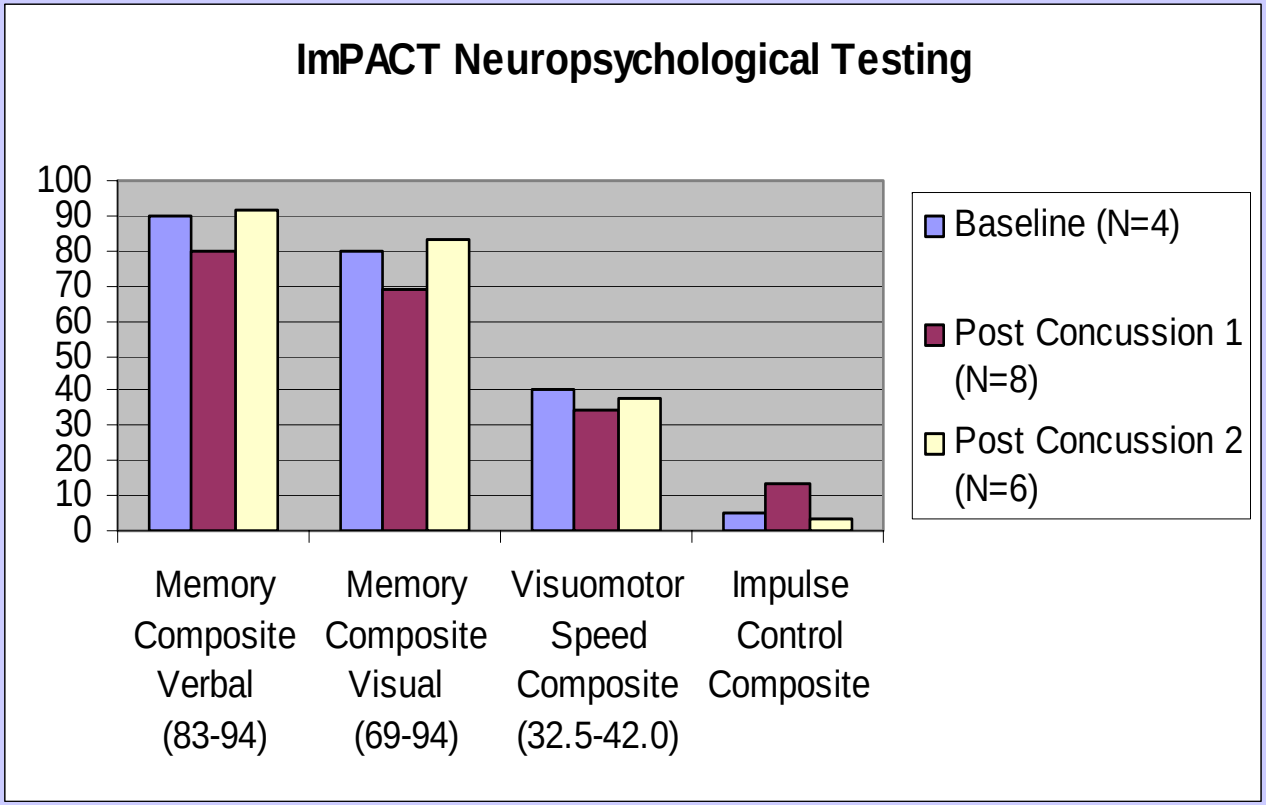

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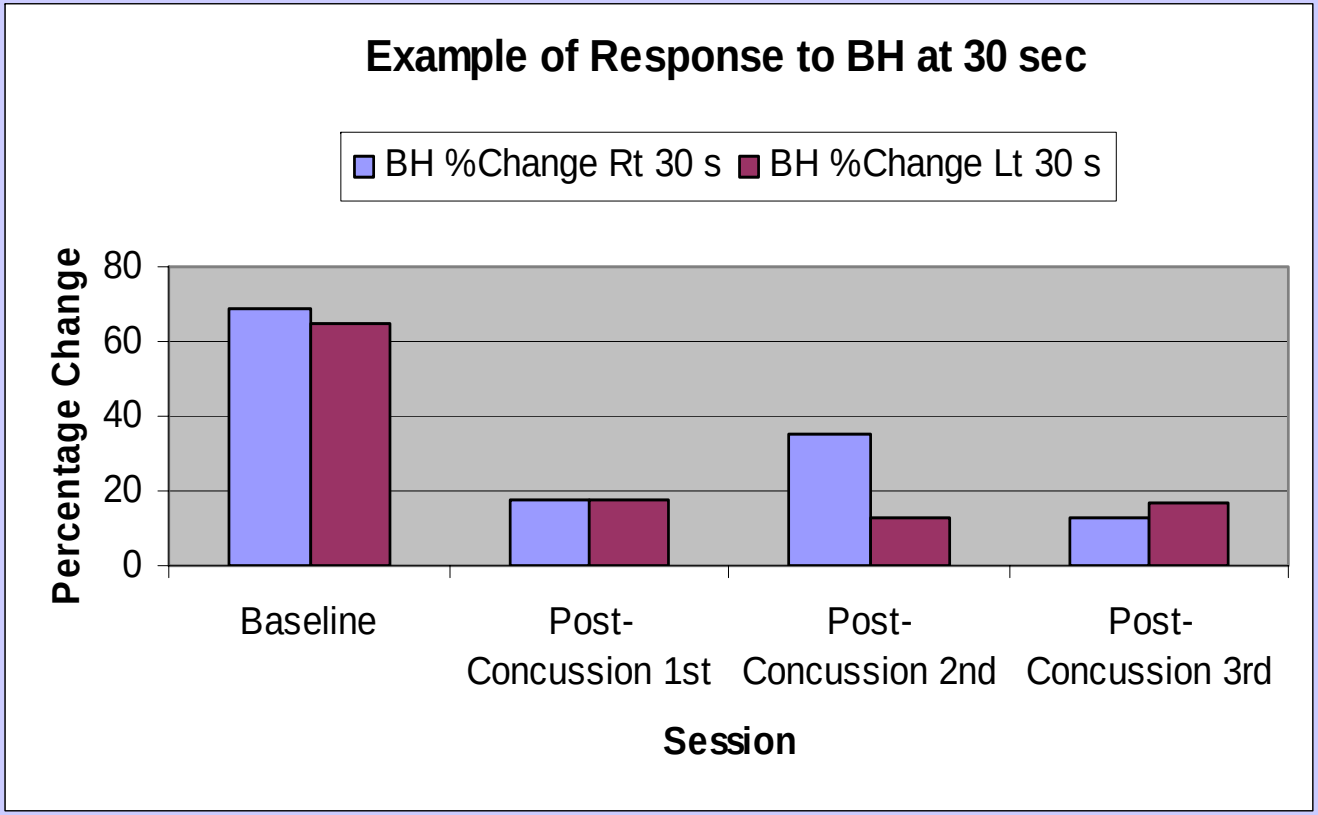

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Preliminary DVA analysis done on the routine TCD data from 4 athletes before and after concussion suggests the presence of altered cerebrovascular function post-concussion. Figures show data points plotted to demonstrate the relationship between the mean velocity and PI (Flow Impedance) at baseline, and for three post-concussion studies, as well as the Flow Impedance Index. The graph based on traditional TCD parameters looks like a scatter plot, but DVA is able to demonstrate differences after concussion. There are observable changes suggesting that the distal arterioles/resistance vessels have dilated after concussion, with apparent post-concussion hyperemia. Analysis of the remaining athletes, with and without concussion, as well as the evoked flow testing sessions, is pending.

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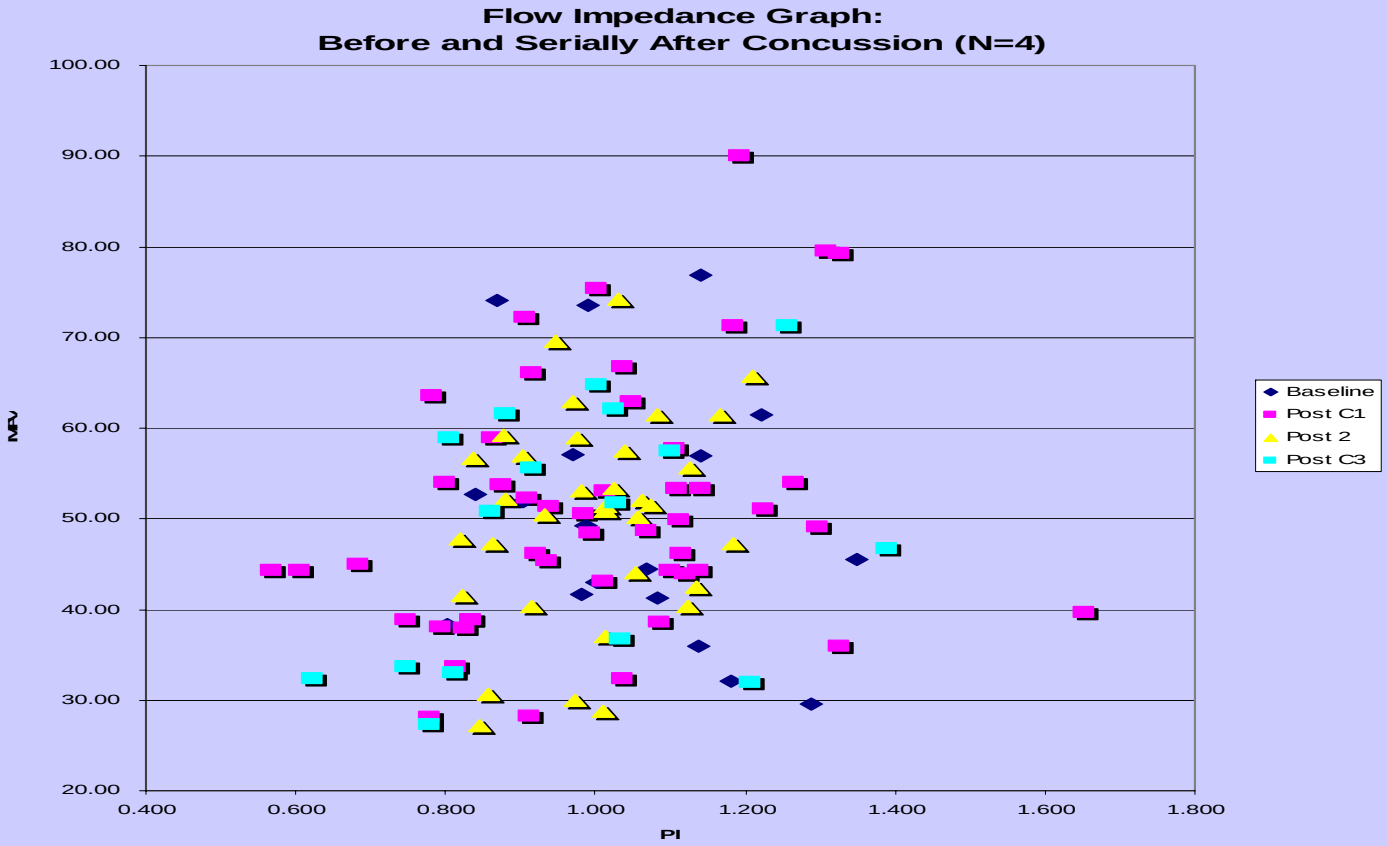

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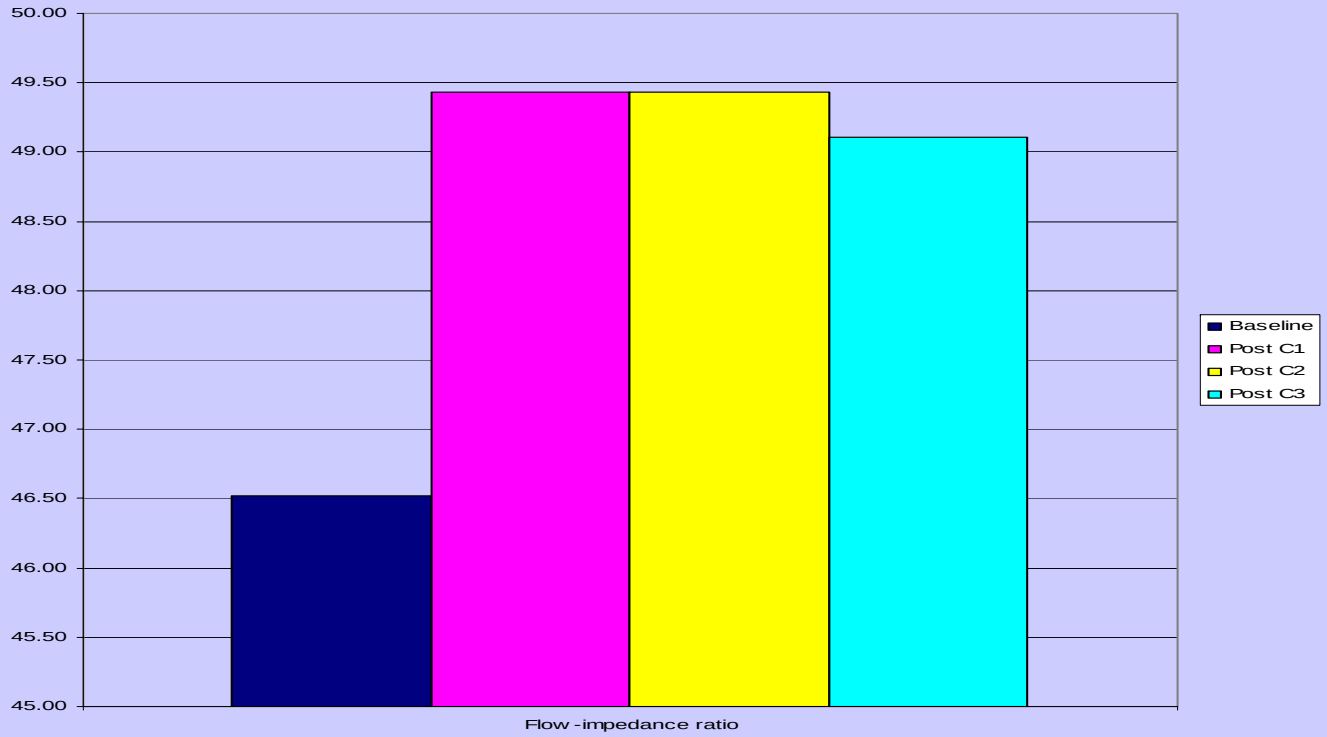
Flow Impedance Ratios:
Before and Serially After Concussion (N=4)



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Conclusion

This Work In Progress study shows that it is feasible to study concussion in amateur athletes, and to assess for changes in neuropsychological function and cerebrovascular function and responsiveness using the methods described. Preliminary results confirm impaired neuropsychological functioning after concussion, which typically improves by a few days after the event. No clear cut differences were observed using traditional TCD parameters, except on evoked flow testing, in which there appears to be changes in response to breath holding after concussion. The addition of DVA reveals changes in cerebrovascular performance after concussion, despite the small numbers of subjects, suggesting measurable differences in the Flow Impedance relationship, and post-event hyperemia. Further analysis of this data set is pending, but TCD testing, especially with DVA analysis, can show altered cerebrovascular function after sports-related concussion. Understanding gained from such information may suggest acute treatments to limit severity and duration of injury, and might be useful as another objective measure to assist with return to play decisions.

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