

## The Canadian Concussion Centre



### Speaker Presentations

#### **1. Chronic Traumatic Encephalopathy-Like Neuropathological Findings without a History of Trauma**

**L-N Hazrati**

Chronic traumatic encephalopathy (CTE) is a neurodegenerative disease characterized by neurocognitive decline and abnormal neuronal and glial deposition of hyperphosphorylated-tau in a pattern distinct from other tauopathies. These changes are hypothesized to occur following repeated mild traumatic brain injury. We report a case of CTE-like neuropathological changes, and features of motor neuron disease in a patient without history of either head trauma or participation in activities associated with increased risk of concussive or sub-concussive blows.

A 45-year-old man with a 7-year history of clinically diagnosed amyotrophic lateral sclerosis was discovered dead by his wife following a 4-hour unattended sleep. Microscopically, neurofibrillary tangles and neuropil threads were seen in the frontal and temporal cortices in the superficial cortical layers, in the depths of sulci, and surrounding blood vessels. Glial tau pathology included astrocytic tangles in a perivascular and subpial distribution. TDP-43 inclusions were seen in the spinal cord. No MAPT mutations or C9ORF72 repeat expansions were detected.

Although CTE has been found only in patients with a history of head trauma thus far, our case potentially highlights the complexity in the pathogenesis of this disorder.

#### **2. Tau PET Imaging in Retired Canadian Football League Players Using [18F]AV-1451**

**CR. Burke, P. Rusjan, K. Misquitta, A. Tarazi, MW. Hussain, M. Al-Atwi, S. Houle, A. Wilson, M. Khodadadi, R. Green, B. Collela, CH. Tator, MC. Tartaglia**

Chronic traumatic encephalopathy (CTE) is a neurodegenerative disease associated with repeated concussions. There is currently no method for making an in vivo diagnosis. The positron emission tomography (PET) radioligand [18F]AV-1451 has a strong affinity to abnormal tau, the pathological substrate of CTE. Retired Canadian Football League players (n=21, mean age=57.4) and controls (n=10, mean age=62.6) underwent [18F]AV-1451 PET and a neuropsychological assessment. Standardized uptake value ratios (SUVr) were calculated across the brain relative to cerebellum. Players were divided into “diffuse” (n=5) and “localized” (n=16) [18F]AV-1451 groups using the size of largest cluster of voxels above an SUVr of 1.6 with a cutoff based 2 standard deviations above the mean cluster size in controls. The “diffuse” and “localized” groups were compared for Personality Assessment Inventory

(PAI) scores of mania, anxiety, anxiety-related disorders, depression, and aggression and the total number of self-reported symptoms across the domains of memory, executive function, behaviour, constitutional, language, motor, sensory, vision, and headache. The “diffuse” group was younger than the “localized”  $45.2 \pm 11.6$  vs.  $61.2 \pm 11.9$ ,  $p=0.016$ , respectively. The mean number of concussions was similar between the groups (diffuse=4.6, localized=4.0). The groups differed in mania (diffuse=58.8, localized=47.8,  $p=0.037$ , Cohen’s  $d=1.03$ ), anxiety (diffuse=49.6, localized=41.9,  $p=0.042$ , Cohen’s  $d=1.00$ ), depression (diffuse=57.0, localized=45.2,  $p=0.029$ , Cohen’s  $d=1.09$ ), and aggression (diffuse=60.6, localized=48.3,  $p=0.005$ , Cohen’s  $d=1.45$ ) scales of the PAI, but not the anxiety-related disorders scale (diffuse=47.4, localized=41.3,  $p=0.182$ ). There was a trend for a greater mean total number of symptoms in the diffuse group (diffuse=26.4, localized=12.8,  $p=0.063$ ). This study shows the potential of [18F]AV-1451 for diagnosing CTE in vivo.

### **3. Self-Paced Saccadic Eye Movements and White Matter Integrity in Patients with Post-Concussion Syndrome**

**F. Taghdiri, J. Chung, S. Irwin, N. Multani, A. Tarazi, A. Ebraheem, M. Khodadadi, R. Goswami, R. Wennberg, K. Davis, D. Mikulis, R. Green, CH. Tator, M. Eizenman, MC. Tartaglia**

A reliable diagnostic biomarker for post-concussion syndrome (PCS) is lacking. Saccades are rapid eye movements. Controlling saccades involves a variety of cognitive processes. Our study aims to assess self-paced saccadic eye movements (SPSEM) as a biomarker of symptom burden and white matter (WM) tract integrity in patients with PCS. In this study, 65 PCS patients (mechanism of injury: sport:40%, motor vehicle accident:4.6%, and multi-mechanisms: 55.4%) and at least 2 concussions performed SPSEM using the Visual Attention Scanning Technology (VAST). We evaluated the relationship between performance on VAST and integrity of major WM tracts involved in visual processing (uncinate fasciculus (UNC), cingulum (Cg), superior longitudinal fasciculus (SLF), and corpus callosum (CC)) derived using tractography of diffusion tensor data. We categorized the patients based upon median of number of SPSEM into two groups: Low saccade frequency group (LS) versus High saccade frequency group (HS). Total number of concussion symptoms reported by the PCS patients as well as number of executive symptoms and constitutional symptoms were significantly higher in patients in LS compared to patients in HS ( $32.3 \pm 8.5$  vs.  $21.5 \pm 13.4$ ,  $p=0.001$ ,  $4.1 \pm 1.3$  vs.  $2.30 \pm 1.9$ ,  $p<0.001$ , and  $6.11 \pm 1.9$  vs.  $3.96 \pm 3.1$ ,  $p=0.003$ , respectively). A positive correlation was observed between number of SPSEM and the fractional anisotropy of left UNC, and left Cg ( $r=0.444$ ,  $p=0.001$ ; and  $r=0.503$ ,  $p<0.001$ ; respectively). In conclusion, decreased number of SPSEM reflects higher symptom burden as well as alterations in WM tracts involved in visual processing in PCS patients.

### **4. Varsity Football Players Show Significant Changes in P3b Event-Related Potentials Due to Accumulated Sub-Concussive Head Impacts**

**JS. Brooks, JW. Thompson, JP. Dickey**

Concussion has been a focus in football at all levels of participation. However, there is a growing appreciation that repetitive sub-concussive impacts may have more significant effects on overall neurological health than the isolated diagnosed concussions that have been the focus of recent research. To evaluate the relationship between the number of head impacts that players experience throughout the season and their P300 evoked potential. We hypothesize that there will be changes in P300 at midseason and postseason depending on the number of head impacts and player skill group, and that players will return to baseline after the season.

Canadian university football players (n=45) were separated into three groups based on player mass and position/skill (small-skilled, big-skilled and big-unskilled). Groups were separated into low and high levels of impact exposure based on the total number of head impacts experienced in-season, recorded using helmet-mounted impact measuring devices (gForce Tracker, Markham, Ontario). Players completed baseline, midseason, postseason, and follow-up (four months) neurophysiological tests to measure P300 evoked potentials. High versus low impact subgroups for each player group were compared. Small-skilled and big-skilled players showed significant decreases in P300 responses at midseason and postseason for high impact players compared to low impact players. Follow-up measures revealed that all groups returned to baseline. Players that experience a large number of head impacts in varsity football demonstrate significant decreases in key measures of cognitive function and information processing.

## **5. Predictors of Clinical Recovery Following Sport-Related Concussion**

### **G. Iverson**

There is tremendous interest in identifying factors that might influence outcome from sport-related concussion. This presentation will review the world literature on predictors of clinical recovery following concussion. Loss of consciousness and brief post-traumatic amnesia are not reliable predictors of outcome. The strongest and most consistent predictor of slower recovery from concussion is the severity of a person's initial symptoms in the first day or initial few days following injury. Those with a pre-injury history of mental health problems appear to be at greater risk for having persistent symptoms. Those with ADHD or learning disabilities do not appear to be at substantially greater risk for persistent symptoms. There is some evidence that the teenage years, particularly high school, might be the most vulnerable time period for having persistent symptoms—with greater risk for girls than boys.

## **6. Tracking Functional Recovery Following Concussion Using Cognitive-Motor Integration**

### **A. Pierias, J. Hurtubise, C. Hughes, A. Macpherson, L. Sergio**

Our research examines cognitive-motor integration during eye-hand coordination. Such integration is often required when performing non-standard visuomotor tasks, where a rule is used to align the required motor output to the guiding visual information. We propose that cognitive-motor integration provides a simple, fast behavioural measure to track functional recovery following concussion. Previous cross-sectional research from our laboratory<sup>1,2</sup> has shown cognitive-motor integration declines in university-level, child, and adolescent athletes who have a history of concussion (but were deemed recovered at the time of evaluation). To extend our research into concussion recovery, the current longitudinal study examines cognitive-motor integration in young adult athletes going through their return-to-play protocol following concussion. Participants (n=10, mean age 19 years 9 months (1.73), 3 females) were tested on two visuomotor transformation tasks using an ASUS tablet touch-sensitive computer attached to an external monitor or external touchpad. They made movements from a central target to one of four peripheral targets (up, down, left, right) by sliding their finger across the horizontally-placed touch-sensitive tablet displaying the targets. In condition one, participants viewed the targets on the touch-sensitive tablet. In condition two, participants viewed the targets on the upright, vertically oriented external monitor, with the cursor feedback 180° reversed so that the motion plane and cursor alignment were decoupled from guiding visual information (requiring cognitive-motor integration). We observed that, compared to their own baseline, these athletes continued to show performance impairments at the time they were cleared to return to their sport based on current return-to-play protocols<sup>3</sup>. Specifically, we found movement path length, movement time, and accuracy impairments relative to baseline ( $p < 0.05$ )

during cognitive-motor integration, a skill that is often needed on the field of play. These data suggest that the current return to play protocols do not fully capture functional abilities needed for many sports, and their impairment may underlie the increased vulnerability to further concussion.

## **7. Cardiac Autonomic and Cerebrovascular Dysregulation Throughout Clinical Recovery in Adolescent Concussion**

**CS. Balestrini & ME. Moir (joint presentation), KC. Abbott, M. Johnson, LK. Fischer, D. Fraser, K. Shoemaker**

A. Although at epidemic levels in adolescents, objective indicators of neurologic damage in concussion remain poorly described.

Characterization of autonomic regulation during dynamic changes in postural stress to examine underlying neurological outcomes associated with acute concussion and clinical recovery.

Clinically diagnosed adolescents (n=35; 14 males, 21 females; age  $15\pm 1$  range=12-18) were examined for up to 6 weekly visits and compared with age and activity level-matched controls (n=35; 19 males, 16 females; age  $14\pm 2$  range=12-18). Heart rate variability (HRV), through the root mean square of successive differences in R-R intervals (RMSSD), and heart rate (HR), were assessed during postural changes throughout a sit-to-stand protocol.

RMSSD was lower in concussed adolescents when compared with controls during baseline sitting ( $41\pm 24$  vs.  $60\pm 40$ ;  $p<0.05$ ). Compared with the first visit, seated RMSSD in patients increased ( $43\pm 25$  vs.  $51\pm 36$ ;  $p=0.05$ ) by the time of clinical discharge (n=31). Upon standing (10 seconds following postural change to standing), RMSSD was lower in concussed adolescents versus controls ( $13\pm 7$  vs.  $18\pm 12$ ;  $p<0.05$ ). Compared with the first visit, standing RMSSD did not improve in patients over the six week recovery period. Compared with controls, seated HR was higher in the concussion patients, an effect which continued throughout the sit-to-stand protocol ( $79\pm 13$  vs.  $72\pm 12$ ;  $p<0.05$ ).

Conclusion: Autonomic regulation of seated HRV is impaired following concussion in adolescents but recovered to levels seen in the control population within 3-6 weeks. Thus, the orthostatic stress of the seated position may be a tool to study autonomic neural control in concussion.

B. Concussions disproportionately affect pediatrics and ongoing maturation places this population at increased risk for prolonged recovery, persistent symptoms, and long-term impairments in cognitive functioning. Currently objective markers of concussion are not described limiting clinical care to subjective measures. Cerebrovascular outcomes following adolescent concussion are not well understood and may provide a useful biomarker of concussion. To assess dynamic cerebral autoregulation (CA) in adolescents following a concussive injury. Twenty-two concussed adolescents (CONC; 13 females;  $15\pm 1$  years;  $26\pm 20$  days post-injury) and twenty-seven healthy controls (CTRL; 15 females;  $14\pm 2$  years) completed a sit-to-stand task. CONC were followed through 6-weeks of rehabilitation. Arterial blood pressure (ABP; finger photoplethysmography; Finometer) and cerebral blood flow velocity (CBFV; transcranial Doppler ultrasound; Multigon Inc.) were measured continuously. Cerebrovascular resistance was calculated and the rate of regulation (RoR) was determined.

The standing-induced drop in ABP was similar between CONC and CTRL ( $25\pm 8$  vs.  $24\pm 7$  mmHg;  $p=0.62$ ). Time to ABP nadir was longer in CONC compared with CTRL ( $7.2\pm 1.1$  vs.  $6.1\pm 1.3$  sec;  $p=0.002$ ). Similarly, time to CBFV nadir was longer in CONC compared with CTRL ( $5.9\pm 1.4$  vs.  $4.4\pm 2.0$  sec;  $p=0.003$ ). With postural changes, CONC demonstrated a reduced RoR when compared with CTRL ( $0.16\pm 0.04$  vs.  $0.21\pm 0.06$  sec<sup>-1</sup>;  $p=0.005$ ). However, at CONC final visit, RoR improved to levels similar to CTRL ( $0.20\pm 0.08$  vs.  $0.21\pm 0.06$  sec<sup>-1</sup>;  $p=0.55$ ).

Impairments in CA are evident in adolescents following concussion. RoR appears to be a promising biomarker and may serve as a useful tool aiding decisions around diagnosis, rehabilitation, and recovery.

## **8. ADHD Symptoms in Youth are Differentially Associated with Polygenetic Risk and Neural Substrates If There Is a History of Traumatic Brain Injury**

**AL. Wheeler, S. Stojanovski, D. Felsky, J. Viviano, M. Chakravarty, S. Ameis, A. Voinesekos, R. Schachar**

Attention Deficit/Hyperactivity Disorder (ADHD) is a major sequelae of traumatic brain injury (TBI) in youth. To examine whether 1) genetic risk for ADHD and 2) altered brain structure; differentially predict ADHD symptoms in youth with and without a history of TBI.

In a large sample of youth we investigated 1) interactions between history of TBI and polygene scores (PGS) with ADHD symptoms (TBI=311, NoTBI=2269) and 2) interactions between history of TBI and neuroimaging phenotypes relevant to TBI and ADHD with ADHD symptoms, namely frontal white matter tract fractional anisotropy (FA) (TBI=121, NoTBI=674) and basal ganglia volumes (TBI=133, NoTBI=754). PGS was associated with ADHD in those without a history of TBI but not in youth with a history of TBI. FA in the genu of the corpus callosum and left anterior corona radiate was positively associated with ADHD symptoms in youth without a history of TBI but negatively associated with symptoms in youth with a history of TBI. Volume in the left and right globus pallidus was not associated with ADHD symptoms in youth without TBI but negatively associated with symptoms in youth with a history of TBI. Volume in the left striatum was negatively associated with ADHD symptoms in youth with and without history of TBI. ADHD associated with TBI is a result of mechanical insult to similar and distinct neural pathways than those affected by genetic risk in developmental ADHD. These results have implications for prognosis and treatment targets for ADHD symptoms following TBI.

## **Poster presentations:**

### **9. Visuomotor Reaction Time Deficits in Athletes with a History of Concussion**

**K. Dalton, A. Willms**

Visuomotor reaction time (VMRT) has been shown to be reduced following acute concussion injuries in athletes, however little is known about the long-term impact of concussion on VMRT.

The purpose of this study was to examine VMRT in athletes with and without a history of concussion.

Intercollegiate varsity team-sport athletes with and without a history of concussion were recruited. Concussion history, including number of previous concussions, was determined with a questionnaire. VMRT was assessed for both the central and peripheral fields of view using the SVT reaction time board. 24 athletes (6 male) completed the study. 54% of athletes had at least one concussion; 38% of athletes reported having two or more. No difference was found in central VMRT between females with and without concussion ( $F(1,16) = 0.001, p = 0.973$ ). There was a trend towards longer peripheral VMRT in females with concussion ( $F(1,16) = 1,291, p = 0.273$ ) which was more pronounced in females with multiple concussions ( $F(1,15) = 2.171, p = 0.161$ ). There was also a trend towards longer peripheral VMRT in male s with multiple concussions compared to males with one concussion ( $F(1,3) = 2.480, p = 0.213$ ). Although not statistically significant due to small sample sizes, there appears to be a trend towards peripheral VMRT being longer in athletes with a history of concussion, particularly athletes with multiple concussions. More research is needed, but these findings suggest that peripheral VMRT could provide information about the long-term impact of sports-related concussion.

## **10. Impact of Comorbid Conditions on Persistent Concussion Symptoms**

**L. Langer, M. Bayley**

Concussion is the most common form of brain injury. Most symptoms resolve spontaneously within weeks of the injury however up to 20% of people can have persistent symptoms that require multiple physician visits for treatment. We hypothesized that pre-existing conditions such as migraines, vestibular problems, or mental health problems would increase the likelihood of development of persistent symptoms. Administrative databases available at the Institute for Clinical and Evaluative Sciences (ICES) were used to identify residents in Ontario diagnosed with concussion between 2008 and 2013. Comorbid conditions were identified by examining physician 5 years prior to injury. The cohort was then tracked using their unique health card identifier for 2 years after the index concussion to determine those with persistent symptoms as defined by those requiring 2 specialist visits i.e. neurology, physiatry, psychiatry, otolaryngology, 3 months after index date for concussion symptoms.

888,472 people were diagnosed with concussion from 2008 to 2013; 305,665 had persistent symptoms. People with the following pre-existing conditions were more likely to require persistent symptom care after concussion: neurological disorder (Odds Ratio 3.1), vestibular conditions (2.1, OR) and sleep disorders (2.2 OR) ( $p < 0.001$ ). This group receive an average of 6.5 specialist visits ( $p < 0.0001$ ), and visit more than 2 types of specialists for their treatment. Other comorbidities that were associated with increased health care utilization were mental health conditions (2.1 OR), pain disorders (2.1 OR), headaches (1.7OR), and prior concussions (1.3 OR). These findings identify a high-risk post-concussion group that clinicians can proactively target for earlier intervention to potentially reduce the duration of symptoms.

## **11. We Know that Soccer Has a High Rate of Concussions, but How Large Are These Head Impacts?**

**A. Harriss, A. Naik, LS. Nagamatsu, DM. Walton, JW. Thompson, JP. Dickey**

More than 265 million people play soccer, and research has unequivocally demonstrated that females and youth players are at a significant high risk of concussion. Recently, concerns for “heading” have been raised due to possible adverse neurological effects. While head impact accelerations and rotations have been investigated in American football, head impacts in youth soccer have not been rigorously studied.

To measure impact accelerations that result from headers in different game scenarios during youth soccer games, 16 players on an elite U-14 female youth soccer team were fitted with headbands instrumented with wireless sensors (GForceTracker, Artaflex Inc., Markham, Ontario, Canada) during eight soccer games. All games were video recorded to characterize heading scenario (Eg. corner kicks). Peak linear acceleration and peak rotational velocity were recorded for each header.

A total of 126 header impacts were recorded, and long-range kicks accounted for 40% of all headers. Average header peak linear acceleration was 16.78 g and ranged from 7.96 g (ball deflection) to 38.62 g (drop kick). Average header peak rotational velocity was 1063 °/s and ranged from 37 °/s (long-range kick) to 2791 °/s (long-range kick). Header accelerations experienced by youth soccer players depend on game scenario with largest impact accelerations from drop kicks and long-range kicks. Although the number of head impacts is smaller in soccer compared to American football, the impact magnitudes are comparable.

## **12. Abnormal Resting State EEG Synchronization in Post-Concussion Syndrome and Chronic Pain** **DM. Buchanan, T. Ros, R. Nahas**

Quantitative-electroencephalography (qEEG) is a low-cost and non-invasive neuroimaging modality useful for identifying specific subtle electrophysiological changes in the brain after a concussion (Thatcher et al., 2001; Ayaz et al., 2015). The disconnection of networks in the brain after concussion results in detectable changes in neuroelectrical transmission (Rapp, 2015) in local and remote neural populations (Erik et al., 2015) (impairing cognition, behaviour, emotion, etc.). This may respectively be detected in qEEG as aberrant spectral power (amplitude), or as aberrant phase-locking value (functional connectivity) (Cao et al., 2010). Changes in power and functional connectivity are shown to correlate with changes in neuro-inflammation (Scott et al., 2015), and with cognitive, behavioural, and emotional symptoms exhibited in post-concussion syndrome (PCS) (Zhu et al., 2014; Dunkley et al., 2015).

Individuals who develop PCS and chronic pain after a motor vehicle accident (MVA) will present increases in power across select low-frequency bands which will also exhibit a coincident reduction in phase-coherence. We conducted a retrospective case-control study using resting state EEG data from 27 patients with PCS and chronic pain following MVAs, and 27 healthy age- and sex-matched controls (15 male, mean age 48.1). Data were collected using 19 electrodes and analyzed using MATLAB.

Independent sample t-tests revealed significant increases in global spectral power across all frequency bands in the patient group vs. control group ( $p < 0.05$  corrected). Opposing deviations in phase-locking value were found in PCS patients, with significant increases in delta and gamma, and decreases in alpha ( $p < 0.05$  corrected). The present study provides evidence for the clinical usefulness of qEEG biomarkers such as power and functional connectivity. The incremental goal of our research program is to identify biomarkers specific to PCS independent of chronic pain, and vice versa, to help clinically differentiate between these potentially co-morbid conditions.

## **13. Impaired Heart Rate Response During Brief 30% Isometric Handgrip in Adolescents Diagnosed with Concussion**

**Woehrle, KC. Abbott, ME. Moir, CS. Balestrini, AL. Barker, LK. Fischer, D. Fraser, K. Shoemaker**

Pediatric concussions are a public health epidemic. Cardiac autonomic function is impaired in concussed adult populations, but its presence as an objective neurological marker of concussion in adolescents remains uncertain. A simple measurement of cardiac autonomic function is the rapid heart rate (HR) response at the onset of moderate intensity handgrip exercise, primarily reflecting cardiovagal control.

Compare the pressor and heart rate (HR) response during a brief isometric handgrip (HG) in concussed adolescents to age-matched controls. 5 concussed adolescents (CON; 4 females; age  $15 \pm 2$  yrs) and 13 age-matched controls (CTRL; 4 females, age  $14 \pm 2$  yrs) performed repeated bouts of isometric handgrips at 30% maximum voluntary contraction. HR (ECG) and hemodynamic responses (photoplethysmographic Finometer) were recorded from 30s of baseline and the last 10s of each HG. A two-way repeated measures ANOVA assessed cardiovascular changes to each HG stimulus. Independent t-test/Mann-Whitney U analyses confirmed hemodynamic values at baseline were not different between CON and CTRL. A group x time interaction was detected for change in HR between CON and CTRL ( $p < 0.05$ ; Cohen's  $d = 1.36$ ). Pairwise comparisons indicated that HG evoked an increase in HR from baseline amongst CTRL participants ( $\Delta HR = 7.3 \pm 6.6$ ;  $p < 0.001$ ) but not in CON patients ( $\Delta HR = 0.8 \pm 1.6$ ;  $p = 0.77$ ). No group-based interactions were detected for change in MAP, SBP, DBP, CO or SV.

These preliminary results reflect a reduction in the ability to remove cardiovagal HR constraint in concussed adolescents, supporting the hypothesis of neural cardiac dysregulation in this group.

#### **14. Emotion-Mediated Executive Function in Adolescents with Post-Concussive Depressive Symptoms**

**RA. Ho, GB. Hall, MD. Noseworthy, C. DeMatteo**

Executive dysfunction and elevated depressive symptoms are prevalent in adolescents following concussion. Evidence suggests a link between cognitive performance and emotional regulation in both healthy and concussed populations. The impact of emotional stimuli on executive control performance has yet to be explored in individuals with concussion who are displaying depressive symptoms.

The purpose was to explore the effect of depressive symptoms on executive function in youth with concussion in the presence of emotional stimuli. Using a prospective cohort design, 30 adolescents diagnosed with concussion between 10-17 years were recruited. The Children's Depression Inventory (CDI) self-report questionnaire was used to divide participants into two groups: Average ( $T < 60$ ) or Elevated ( $T \geq 60$ ) levels of depressive symptoms. Both groups completed an Emotional Go/No-Go task involving task-irrelevant faces (in a 3T MRI scanner) and a neurocognitive test (ImPACT) to assess executive functioning including inhibitory control. Behavioural data from the Emotional Go/No-Go task was assessed in a mixed factorial ANOVA. The effects of emotion and inhibitory control on brain activity were fitted to a general linear model. Z-statistic images were threshold using clusters determined by  $Z > 2.3$  and a corrected cluster significance threshold of  $p = 0.05$ . Eleven participants comprised the Elevated group, of which 72% were hit in occipital region at the time of injury. At least one fifth of participants had impaired performance ( $< 10$ th percentile) on each of the ImPACT cognitive composite scores: verbal memory (33.3%), visual memory (23.3%), visual motor speed (50%), reaction time (56.7%). The Emotional Go/No-Go was unable to detect behavioural between-group differences. The main effects of faces and depressive symptoms on inhibitory control were also not significant. fMRI results revealed group-level activity patterns. Faces activated regions associated with both facial and cognitive processing. However, frontal regions that are usually associated with inhibitory control were not activated. Adolescents with elevated levels of depressive symptoms engaged frontal regions during the task. There are deficits in cognitive function following concussion. Youth with elevated depressive symptoms were more likely to engage in brain regions subserving evaluative processing of social interactions, which might suggest that depressive symptoms display differences in physiology when emotional stimuli are present. This provides insight into the role the environment plays in contributing to the cognitive demands placed on adolescents recovering from concussion.

#### **15. Speech-Language Pathology and Concussion: Evaluating a Return to School Group Model of Intervention among Individuals with Persistent Post-Concussion Symptoms**

**P. Welch-West, AM. Johnson, B. Al-Qenai, JD. Holmes, M. Longval, C. Marshall**

Recent research has focused on guidelines for post-concussion return to play/work/learn, and yet there is still relatively little literature that focuses on specific treatment methods.

This study proposes that a 7-week group intervention will improve self-reported symptom scores.

Participants ( $n = 71$ ; 45 women) were provided with novel strategies for reading, writing, study skills, social communication and technology use. Self-assessment of symptoms was obtained weekly, both before and after each session of the treatment program, in an effort to monitor the cognitive demand of



each session, and to identify the extent to which the program produced an improvement over the course of seven weeks.

Symptoms were transiently exacerbated by treatment,  $F(1, 343) = 255.69$ ,  $p < .05$ , within each week of the program, but overall, the treatment was found to be effective,  $F(6, 343) = 2.29$ ,  $p < .05$ . Post-hoc analysis of means (using Tukey's HSD) suggests that there was a significant improvement ( $\alpha = 0.05$ ) of self-reported symptoms when comparing weeks 1 and 6, and between weeks 1 and 7.

Transient exacerbation of symptoms aside, the intervention produced a statistically significant benefit in the management of persistent concussion symptoms.

## **16. Mindfulness-based Yoga for Youth with Persistent Concussion Symptoms: Bridging Functional and Neurophysiological Outcomes**

**M. Paniccia, R. Knafo, S. Thomas, T. Taha, L. Thompson, A. Ladha, N. Reed**

Limited interventions address persistent concussion symptoms in youth in a way that targets functional and neurophysiological outcomes. Mindfulness-based yoga (MBY) is a mind and body intervention that focuses on the present moment, with a purposeful attention on breath and awareness of thoughts. Heart rate variability (HRV) is emerging in concussion research as a neurophysiological measure that captures an individual's ability to be flexible and adaptable in their environment. Examining HRV in the context of MBY can provide insights into a youth's ability to self-regulate in the context of persistent concussion symptoms. Investigate the impact of MBY on participation, self-efficacy and HRV in youth with persistent concussion symptoms over pre-, post- and 3 months following MBY.

Case series design. Youth ages 13-17 years old ( $N=6$ ) participated in an 8-week MBY intervention, 1x/week, for 45 minutes. Participation, self-efficacy and heart rate variability (24 hours) were collected pre-, post-, and 3 months following mindfulness-based yoga. Heart rate variability was also collected during each mindfulness-based yoga session.

Trends towards increasing self-efficacy in academic, social and emotional domains were found following MBY and maintained at the 3-month follow-up. Trends of increasing HRV were also found following intervention and across the 8 sessions of MBY. Concussion symptoms across physical, cognitive, fatigue and emotional domains illustrated trend of significant decline following MBY and maintenance at 3-month follow-up. MBY is a functional intervention that can potentially have a direct impact on youth with persistent concussion symptoms, improving their self-efficacy and neurophysiological function. Future research is warranted.