

The Canadian Concussion Centre Presents:



**7<sup>th</sup> Annual Concussion Research Symposium**  
Advances in Concussion research,  
Including Concussion in Women and Girls  
Saturday, Nov 2, 2019- BMO Education and Conference Centre

Speakers Presentations

**1. Concussion History, Career Status and Cumulative Years of Football Exposure Influence Concussion Assessment Performance in Elite Football Players**

B. Cookinham, M. Weber, C. Swank, A. Medley, K. Brizzolara

Background: 61% of retired football players report sustaining a concussion during their professional career. However, the influence of concussion history, career status and cumulative years played on total symptoms, symptom severity, neurocognitive function, and balance is largely unexplored.

To explore relationship of concussion history, career status, and years of football exposure on total symptoms, symptom severity, neurocognitive function, and balance in elite football players.

Elite football players (n=102; age M=27.75±6.95 years) without a concussion (>30 days) underwent SCAT-3 assessments. Players were placed into a low (0–1) or multiple concussion (2+) history group and categorized by career status (draft prospects, active professional players and retired professional players). Data were analyzed using regression analyses.

Multiple concussions group reported 3.07 times greater total symptoms, 3.58 times higher symptom severity, and lower SAC scores (1.42 points) compared to low concussion group. Professionals reported 1.88 times greater total symptoms and 2.35 times higher symptom severity compared to draft prospects. Retired players reported 7.07 times greater total symptoms, 8.97 times higher symptom severity, lower SAC scores (1.98 points), and 3.67 more m-BESS errors, compared to draft prospects. Players with 11-19 years football exposure reported 3.83 times higher symptom severity compared to players with <11 years football exposure. Players with >19 years football exposure had 6.87 times higher symptom severity than players with <11 years football exposure. All results presented, p<.05.

Retired players with multiple concussions and 19+ years of football exposure are likely to have more symptoms, higher symptom severity, and lower neurocognitive scores.

## **2. Chronic Traumatic Encephalopathy (CTE) is absent from a European Community-Based Aging Cohort**

G.G. Kovacs, S.L. Forrest, J.J. Kril, S. Wagner, S. Hönigschnabl, A. Reiner, P. Fischer

The last decade has seen increased awareness of chronic traumatic encephalopathy (CTE) described predominantly in professional athletes. CTE is a neuropathological diagnosis. Ageing-related tau astroglial pathology (ARTAG), however, involves similar anatomical locations and may co-exist with CTE.

Objective: To determine the prevalence of chronic traumatic encephalopathy (CTE) and cortical aging-related tau astroglial pathology (ARTAG) in a European community-based population (n = 310).

The frontal, parietal, and temporal cortices, representing initial stages of CTE were assessed using immunostaining for phospho-Tau (AT8).

No case fulfilling CTE consensus criteria was found. However, isolated astroglial or neuronal tau pathologies were recognized in the depths of cortical sulci (<2%). ARTAG was identified in 117 cases (38%), with a similar regional prevalence. Gray matter ARTAG was the most common followed by subpial, white matter, and perivascular. Using a strict definition of CTE pathology demonstrates that CTE is absent in an unselected European community-based ageing population where the incidence of repeated mild traumatic brain injury is low. In contrast, cortical ARTAG in this population is common. ARTAG in isolation might not be indicative of CTE although commonalities in pathogenesis should be considered. We propose the separate evaluation of components of CTE as a conceptual approach to better define the earliest stages and progression of CTE in individuals with well-documented history of repeated mild TBI.

## **3. Multimodal Brain Imaging Fusion Augments Blood Biomarkers for Post-concussion Syndrome**

J.R. Kozloski, S. Sihag, S. Naze, F. Taghdiri, C.H. Tator, R. Wennberg, D. Mikulis, R. Green, B. Colella, M.C. Tartaglia

The search for biomarkers of neurological outcomes after concussion is integral to designing new therapies to aid recovery. Mitigating risk of post-concussion syndrome (PCS) and neurodegeneration are key areas requiring clinical correlates of neuronal tissue and cell modification and death. Neurofilament light (Nfl) has emerged as a key blood biomarker for individuals at risk [1]. We wondered if applying new Graph Signal Processing (GSP) techniques to multimodal brain imaging might identify correlates of blood biomarkers and augment prediction of subject risk.

We aimed to assess appropriateness of GSP for fusing diffusion and functional magnetic resonance imaging (dMRI and fMRI) and creating structure/function biomarkers for PCS that correlate with Nfl.

Multimodal brain imaging data was provided by University Health Network's collection from former athletes with history of concussion and healthy controls. Structural connectomes were represented as a graph with nodes derived from cortical regions and connection matrix from dMRI. Graph frequencies represented the extent of spatial

variation in blood oxygen level dependent (BOLD) signals. We applied GSP to identify brain regions with significantly different high and low graph frequency components among former athletes and healthy controls.

Graph signal processing analysis of different signals generated across the physical structure of the brain provided new insights and corroborated existing clinical findings regarding brain changes linked to PCS. In addition, GSP results correlate with blood Nfl and predict levels from both former athletes and healthy controls.

GSP is appropriate for multimodal fusion of brain imaging data and construction of PCS biomarkers that correlate with Nfl.

#### **4. Resting State Functional Connectivity as a Biomarker of Longitudinal Changes in Former Athletes with Multiple Concussions**

A. Vasilevskaya, F. Taghdiri, C.S Burke, A. Tarazi, S.A. Naeimi, M. Khodadadi, R. Goswami, R. Wennberg, D. Mikulis, R. Green, B. Colella, K. Davis, C.H. Tator, M.C. Tartaglia

There are currently no biomarkers of longitudinal deleterious effects of concussions. Assess the use of resting state functional connectivity as a biomarker of longitudinal changes in a cohort of former contact sports athletes.

25 former (24 professional, 1 semi-professional) contact sports athletes [all males; age (53.12±13.83); concussions (Median=2, Min=0, Max=16)] were recruited.

Assessments completed at baseline & 2-year follow up: full

neuropsychological/neurological battery, MRI & cerebrospinal fluid collection to exclude Alzheimer's disease. Results were age & multiple comparison corrected.

Resting state functional connectivity within the salience network significantly decreased over time between the right anterior insula (AI) and the following areas: right supramarginal gyrus (SMG) (T=-2.87, p-FDR=0.030) & right rostral prefrontal cortex (RPFC) (T=-2.99, p-FDR=0.028). A decrease in connectivity was also observed between the left AI and the following areas: right SMG (T=-3.35, p-FDR=0.028) & right RPFC (T=-2.99, p-FDR=0.028). Finally, a significant decrease in connectivity was seen between right RPFC and the following areas: right SMG (T=-2.98, p-FDR=0.028) & left SMG (T=-3.36, p-FDR=0.028). Using a seed-level correction, a relationship was found in baseline connectivity between left RPFC and right SMG and worsening of depression t-scores (T=3.27, p-FDR=0.023), measured by Personality Assessment Inventory.

Functional connectivity within the salience network significantly decreased over the 2-year period and baseline connectivity was predictive of worsening depressive scores over time. Resting state functional MRI could be a biomarker of longitudinal changes in a cohort of former athletes with multiple concussions and may be a useful endpoint in interventional trials.

## **5. Making the invisible visible: concussion can be reliably classified using the neurophysiological connectome**

J. Zhang, B.T. Dunkley

Concussion diagnoses are challenging given the lack of objective biomarkers. A non-invasive, rapidly acquired, tolerable and effective fingerprint is desirable. Unfortunately, structural measures reported across studies are inconsistent. A direct measure of neural circuits might prove to be a reliable marker of injury – magnetoencephalography (MEG) can measure these circuits. A combination of MEG circuitry data and machine learning (ML) might hold the key to accurate diagnoses.

We applied a comprehensive ML pipeline to MEG neural connectome data to identify biomarkers and develop a classification model for concussion.

Resting state MEG data were collected in 50 participants, 25 acute/sub-acute concussion, 25 matched controls, and functional coupling across brain regions defined by neural oscillations and their interactions. Support vector machine (SVM) and random forest-based feature selection (rRF-FS) algorithms were applied to classify cases of concussion from those without.

Our ML pipeline successfully selected connections important for concussion. Feature selection showed that coupling between 25 regions mediated by neural oscillations in the alpha band (~10 Hz) could generate a classification model with 88% accuracy. Other frequency ranges showed even greater accuracy, with the theta band (~5 Hz) showing 20 functional connections that could delineate concussion with 90% accuracy.

The present study presents a framework that not only identifies neural connections and frequencies of oscillations that can act as fingerprints for concussion but can also classify the disorder with a high degree of accuracy and reliability, using a short 5 minute scan that is well-tolerated and easy to acquire.

## **6. Barriers and Facilitators in Concussion Recovery and Return to Work (RTW) among Adult Women**

D. Beaton, S. Babul

Recent literature suggests that females sustain concussions at a higher rate and have increased risk of experiencing persistent post-concussion symptoms than males. The Concussion Awareness Training Tool (CATT) is a series of free-of-charge online educational modules and resources ([www.cattonline.com](http://www.cattonline.com)). To address concussion among adults, CATT for Workers and Workplaces (CATT W&W) launched June 2019. Focus groups and interviews with workers from various industries across British Columbia informed the development of this resource.

The present study uses a gender lens to understand the barriers and facilitators in concussion recovery and Return to Work (RTW) for women.

Data have been generated through semi-structured in-depth interviews and focus groups with 31 workers (22 women) who returned to work following a concussion or were in the recovery process.

Facilitators include levels of support from family members, colleagues, supervisors, the workplace environment, and certain activities. Barriers include stress, doubt in abilities, stigma, and the 'double shift' of unpaid care and domestic work.

The increasing prevalence and suspected under-diagnosis of concussion within the adult working population is a global issue. Women may not have social or professional supports in place to properly manage concussion recovery and RTW. Gender-specific strategies are needed to reduce both the risk of re-injury and long-term health and economic consequences.

## **7. Examining Return Visits to the Emergency Department after Concussion in Canada**

R. Taylor, L. Morrison, R. Taylor, M. Mercuri, J. Thompson

Due to an increased public awareness, an increased number of patients seek medical care following minor head injuries. Individuals discharged with a diagnosis of concussion often experience ongoing symptoms for days or weeks, prompting concern over recovery and return visits to the ED for additional medical care.

The purpose of this study was to identify: (1) the proportion of patients discharged from the emergency department with a diagnosis of concussion that return within 14 days and (2) the characteristics that prompt a return.

A retrospective chart review was conducted on adult patients with a discharge diagnosis of concussion who accessed care through Hamilton Health Sciences Emergency and Urgent Care departments in 2016. Subsequent data was collected from those who returned to the ED within 14 days. Statistical analyses were performed using STATA/SE version 13.1(StataCorp LP).

Of the 389 patients included in the study, 38 (10%) returned within 14 days. Patients who sustained a concussion in a sport-related context or were referred to a specialized clinic were less likely to return, and this was statistically significant ( $p < 0.05$ ). Of those who did return, 42% received a CT scan with normal results, and 42% were given new discharge instructions.

Approximately 10% of patients diagnosed with a concussion in a Canadian hospital setting returned to the emergency department within 14 days of their index visit.

## **8. Precision-Medicine in Post-Concussion Syndrome by Relating Subject Specific Structural-Functional Connectomes and Neuropsychological Measures**

M. Gumus, M. Mack, R. Green, M. C. Tartaglia

Post-concussion syndrome (PCS) is a heterogeneous condition that includes cognitive impairments, mood disorders and constitutional symptoms including visual disturbances. Currently there are no diagnostic biomarkers for PCS and the heterogeneity of symptoms makes targeted therapies difficult to deliver.

Objectives: To better capture the heterogeneity of the patients, we hypothesized that PCS patients can be separated into clinical subtypes according to different clinical patterns of impairment or symptom.

We created subject specific structural and functional connectomes based on

Diffusion Weighted Imaging (DWI) and Resting State Functional Magnetic Resonance Imaging (rs-fMRI), respectively. We identified sets of gray matter pairs, that showed different coactivation patterns or reduced integrity in white matter tracts that connected the two regions, in PCS patients (N=82) in comparison to controls (N=17). Based on these identified regions, we subtyped PCS patients into severe and mild groups, using a gaussian mixture model.

The PCS group who had lower white matter integrity between Right Cingulate and Pericalcarine scored lower in Stroop Colour-Word Naming Task. Similarly, PCS patients that reported higher number of vision symptoms exhibited greater co-activation of right-left lingual. Our results revealed a subset of PCS patients exhibiting greater structural functional changes as well cognitive deficits and more visual symptoms in comparison to a subset of PCS patients who show similar neuroimaging and cognitive profiles as the healthy controls. The changes may represent abnormalities or compensatory changes and may help characterize the heterogeneity of PCS.

## **9. Depression, Anxiety, and Quality of Life in Postconcussion Syndrome**

C. Doroszkiewicz, C.H. Tator

Postconcussion syndrome (PCS) can last for months, years, or indefinitely and affects a considerable percentage of concussion patients. A longitudinal follow-up analysis was conducted to evaluate the occurrence of anxiety and depression in patients with PCS, measure their quality of life, and characterize the types of treatments they have participated in and their perceived effectiveness of each. A questionnaire package consisting of the Depression and Anxiety Stress Scale (DASS), the WHO Quality of Life Assessment (WHOQOL-Bref), and a general follow-up questionnaire was sent to 526 PCS patients. Responses were received from 105 (20%) patients. A total of 37 (35.2%) patients had symptoms of anxiety, depression, or both. 8 (7.6%) patients had symptoms of depression alone, 8 (7.6%) patients had symptoms of anxiety alone, and 21 patient (20%) had symptoms of both depression and anxiety. The number of previous concussions was significantly correlated with increased DASS anxiety ( $p=0.02$ ) and depression ( $p=0.04$ ) scores. Increased DASS scores were significantly correlated with a poorer quality of life in all four domains of the WHOQOL-Bref. Thus, concussion-related symptoms of depression and anxiety are important public health concerns.

## **10. Overview of General Knowledge About Sport-Related Concussions in the Canadian Population: a Validation and Exploration Study**

S.A. Vinet, L.A. Corbin-Berrigan, S. Guay, L. De Beaumont

Concussion education and prevention strategies rely on concussion knowledge and attitude studies. Such studies suggest that males and females have different attitude towards sport-related concussions, with females being more prone to reporting concussions. It is also suggested that attitude towards sports may alter concussion recognition and knowledge. While many studies are becoming available on the matter, very few used psychometrically validated questionnaires. This is even more problematic when French-speaking Canadians are included as results can be negatively biased by a linguistic barrier or unvalidated translation.

This study is part of a wider research project aiming to characterise concussion knowledge amongst Canadians and associated psychosocial factors, such as attitude towards sports. We aimed to translate and validate the Sport Commitment Questionnaire (SCQ-2) from English to French and study its psychometric properties. Two bilingual individuals translated the SCQ-2 from English to French (SCQ-2fr). Two experts in the sport and concussion field unfamiliar with the questionnaire translated the SCQ-2fr back to English. Then, we consolidated the experts' answers and formed a focus group of 3 experts in the sport domain and 3 members of the general public to validate the final translated version.

Currently at the preliminary pilot testing phase, 80 bilingual individuals (40 females), completed both versions of the SCQ-2. Psychometric properties and validation of the SCQ-2fr will be presented.

SCQ-2fr will allow surveying Canadians in both official languages and gain a better understanding on sport-related concussion knowledge and its associated psychosocial factors, with hopes to create future prevention and awareness avenues.

#### **11. Ecological Validity of a Novel Virtual Reality Test of Attention and Executive Functions in Patients Who Are in the Post-Acute Phase of Mild Traumatic Brain Injury**

E. Jeffay, K. Zakzanis

Several measures have been developed that are purported to be high in ecological validity but few studies have examined their clinical utility with patients who are in the post-acute period of recovery (>90 days) following a mild traumatic brain injury (mTBI). The use of Virtual Reality (VR) has the potential to assess these domains in a more ecologically valid way.

To develop and validate two novel VR-based assessments of attention and executive functions and to compare the return to work (RTW) sensitivity and specificity of these tasks with traditional neuropsychological tests.

50 patients with mTBI who were either employed ( $n = 23$ ) or unemployed ( $n = 27$ ) were administered traditional neuropsychological tests of attention and executive functions along with two novel VR-based tests. Ecological validity was evaluated via a stepwise discriminant functions analysis and means comparison with effect size analysis.

Only the VR-based attention test and the Ruff Selective Attention Test were statistically significant and predictive of group membership. The model predicted group membership with 82% accuracy, which was supported by a split-half cross-validation follow-up analysis. Sensitivity and specificity estimates were 82.6% and 81.5%, respectively. Effect size analysis also corroborated these results.

Performance on tests of attention were sensitive to RTW status in this sample but executive functioning was not. The VR-based attention test was more ecologically valid than any of the other predictors. These findings provide support for the use of immersive technology in determining RTW. Replication studies are needed to validate the current findings.

**12. Is a measure of dual-task performance better able to screen for cognitive impairment in patients with post-concussion syndrome?**

N. Anssari, D. Gold, A. Tarazi, M.C. Tartaglia

Brief neuropsychological screening measures such as Montreal cognitive assessment (MoCA) are normal in most concussed patients, despite reports of cognitive difficulties in daily life. In this study we evaluated whether or not a measure of dual-task performance from the Test of Everyday Attention (TEA) is more sensitive to these cognitive complaints than the MoCA.

Compare MoCA performance with dual-task performance in patients with concussion to evaluate if a dual-task measure is better able to identify performance.

We tested 35 patients who were referred to UHN concussion clinic in Toronto Western Hospital after at least 1 concussion. Cognitive function was assessed using MOCA and Dual Task testing. MoCA score below 26 and Dual Task testing score below 25th percentile, were considered abnormal.

The mean age was 44.7 years with a range of 24-81 years. Our sample included 10 males and 25 females. The mean duration from last concussion was 2.7 years. Sixty five percent of our patients showed abnormal Dual Task test results whereas MoCA was abnormal in only 25 percent of these patients (P value: 0.004).

Though the MoCA is still useful in broadly assessing different domains of cognitive functioning such as language and memory, preliminary findings indicate that dual-task performance may be more sensitive to cognitive dysfunction than the MoCA in patients with concussion.

## **Poster Presentations**

**13. Microstructural Abnormalities in Deep and Superficial White Matter in Youths with Mild Traumatic Brain Injury**

S. Stojanovski, A. Nazeri, C. Lepage, S. Ameis, A. N. Voineskos, A. L. Wheeler  
Diffusion Weighted Imaging (DWI) studies of mild traumatic brain injury (mTBI) have focused on alterations in microstructural features of deep white matter fibers (DWM), though post-mortem studies have demonstrated that injured axons are often observed at the gray-white matter interface where superficial white matter fibers (SWM) mediate local connectivity.

To examine microstructural alterations in SWM and DWM in youths with a history of mTBI and examine the relationship between white matter alterations and attention.

Using DWI, DWM fractional anisotropy (FA) and SWM FA in youths with mTBI were compared to typically developing and psychopathology matched control groups (n=63 each). Following tract based spatial statistics, SWM FA and DWM FA were assessed by applying spatially generated masks. Voxel-wise z-score calculations were used to derive a count of voxels with abnormally high and low FA for each participant. Analyses examined DWM and SWM FA differences between mTBI and control groups, the relationship between attention and DWM and SWM FA, and the relative susceptibility of SWM compared to DWM FA to alterations associated with mTBI.



Group comparisons revealed more voxels with low FA and fewer voxels with high FA in SWM in mTBI youth compared to both control groups. Equivalent comparisons in DWM revealed a similar result, however, no group differences for low FA in DWM were found between mTBI and the control group with matched psychopathology. Slower processing speed on the attention task was correlated with the number of voxels with low FA in SWM in mTBI youths.

This study identified abnormalities in SWM microstructure associated with processing speed in youths with mTBI.

#### **14. Concussion During Adolescence Disrupts local and Large-Scale Neural circuits**

Z. Emami, B.T. Dunkley

Concussion and post-concussive syndrome disproportionately affect youths, as the typical maturational arcs of brain development are perturbed by an injury. Diagnosis is notoriously difficult given the lack of markers on standard radiological scans and the subjective nature of self-reported symptoms.

A reliable and objective biomarker is desirable and magnetoencephalography (MEG) presents an ideal fingerprint source due to its sensitivity at measuring disruption to local and large-scale neurophysiological circuits.

Using MEG we recorded 5 minutes eyes-open resting state in 6 adolescents with a concussion, and 20 without. To quantify local circuits, power spectrum density estimates were calculated with each region, and for large-scale circuits, orthogonalised amplitude envelope correlations were computed for all seed pairs.

We identified significant global increases in delta and theta oscillations in concussion. In contrast to those low-frequency increases, we also found reduced beta power across large regions of the brain. Finally, measures of large-scale circuits showed elevated alpha coupling, predominantly confined to visual cortex.

Consistent with previous literature in adults that posits injury perturbs local inhibitory tone, we observed a slowing or shift from the dominant alpha frequency to slower rhythms, consistent with the idea of changes in e:i balance. Moreover, beta is known to be generated by layer 5 in the cortex and this frequency carries excitatory efferent signals – the reductions we observed suggest injury selectively disrupts excitatory tone. Finally, the elevated alpha coupling suggests deeper disruption and is consistent with thalamocortical dysrhythmia.

#### **15. The 2015 US Soccer Federation Header Ban and Its Effect on Emergency Room Paediatric Concussion Rates in Adolescent Soccer Players.**

R. Lalji, N. Chow, S. Howitt, H. Tamim

In 2015, as a result of ongoing litigation and new research on the risk of headers, the US Soccer Federation banned all headers for players less than 10 years of age. Consequently, players 11-13 were restricted to reduced heading.

To assess change in the proportion of children aged 10-13 playing soccer in the United States presenting to the ER with a concussion relative to all other injuries before and after the 2015 ban on headers.

It is a descriptive epidemiology study.

The National Electronic Injury Surveillance System was used to address our objective. Analysis was restricted to soccer athletes between the ages of 10-13 that reported to US hospital ER's following injury in 2013-2014 and in 2016-2017. Multivariable logistic regression was performed to assess odds of having concussions for 2013-2014 compared to 2016-2017 after controlling for age, gender, and ethnicity.

6.4% of all injury cases resulted in a concussion diagnosis in the two years preceding the ban versus 9.2% of all injuries in the two years following the ban on headers. Concussion in relation to all other injuries showed a statistically significant increase in 2016-2017 when compared to 2013-2014 after controlling for covariates.

There was a significant increase in the odds of ER visits with a concussion relative to other injuries after the header ban (2016-2017) as compared to before (2013-2014). This increase in concussion following the ban on headers contrasts studies in hockey that show reductions in concussion after limiting contact.

#### **16. Bicycling-Related Concussions Leading to Postconcussion Syndrome in Adults**

C. Moore, P. Baharikhoo, M. Khodadadi, C.H. Tator

Concussions among adult bicyclists are common, but little is known about the long-term effects of the consequences of these concussions such as postconcussion syndrome (PCS) including its occurrence, clinical features and recovery potential. Indeed, our study is the first to examine PCS due to bicycling in any age group. We examined patient demographics, concussion mechanisms, and persistent symptoms as factors leading to PCS in adults, and the potential for recovery. We conducted a retrospective chart review of 28 patients age 18 or older who sustained a concussion while bicycling and were referred to the Canadian Concussion Centre for management of PCS. At the time of the last follow-up, 23 (82.1%) patients had failed to recover completely, and patients with one or more previous concussions had a significantly longer duration of PCS ( $p=0.042$ ). Bicycling concussions resulted in a greater mean duration of PCS (23.7 months) than a comparison group of patients with PCS due to collision sports (16.1 months) ( $p=0.07$ ). Adults who sustain bicycling-related concussions and develop PCS often have long-lasting symptoms; greater attention should be given to prevention strategies such as improved bicycling infrastructure and safer bicycling practices to reduce concussions in adult bicyclists.

#### **17. Body Checking in Youth Ice Hockey as a Mechanism of Concussion and Post-Concussion Syndrome**

V. Blanchet, C. Moore, E. Prentice, C.H. Tator

Youth ice hockey is a popular contact sport with a high incidence of concussion. Many studies have shown that body contact, more specifically body checking, results in the highest proportion of concussions experienced during play.

To highlight the prevalence of post concussion syndrome (PCS) with respect to concussions experienced during ice hockey as a result of body checking.

We conducted a retrospective chart review of 87 paediatric patients (between the ages of 10-18) who sustained a concussion while playing ice hockey and were referred to Dr. Charles Tator at Toronto Western Hospital, Canada.

Sixty-eight patients (73.5%) who experienced a concussion during ice hockey also experienced PCS. Body checking as a mechanism of concussion accounted for the majority (52.9%) of concussions during ice hockey and resulted in 39.1% of PCS cases. The mean duration of recovery for patients who experienced their concussion as a result of body checking was 11.18 months  $\pm$  23.7. Patients who were body checked on open ice had the highest duration of symptoms, on average, lasting 14.0 months  $\pm$  29.7. Conclusion. Body checking in youth ice hockey is a significant risk factor for concussion and PCS. Players who sustain a concussion and develop PCS as a result of body checking can have long-lasting symptoms that deserve more awareness. The current policy of Hockey Canada to introduce body checking at the Bantam level (age 13-14) should be revised in accordance with emerging data about the risks associated with concussion, including PCS.

### **18. The Hull-Ellis Concussion and Research Rapid Access Clinic: Cognitive and Psychological Predictors of Recovery at 8 Weeks Post-concussion**

L. Ruttan, M. Bayley, T. Chandra, E. Foster, P. Comper

Cognitive and psychological symptoms are frequently reported in the acute post-concussive period. Psychological symptoms are important to consider given impact on quality of life, potential to exacerbate symptoms in other domains (e.g., sleep, pain) and prolong recovery. Identification of factors that predict poor recovery (i.e., specific cognitive domains or psychological factors) would allow for earlier and targeted intervention leading to improved outcomes.

To determine whether 1. cognitive performance and 2. psychological symptoms at Week 2 post-concussion predict recovery at Week 8 in a non-convenience sample (i.e., varied mechanisms of injury).

102 participants were administered 5 cognitive tests (Trails A & B, WAIS-IV Digit Symbol/Coding/Digit Span, Rey Auditory Verbal Learning Test); 201 participants were administered the Brief Symptom Inventory at Week 2 post-concussion. Physician determined recovered status at Week 8.

Logistic regressions were performed to predict recovery status at Week 8 controlling for group differences between recovered and non-recovered groups.

Cognitive: Better scores on a verbal learning task (RAVLT) were associated (1.14x risk) with unrecovered status at week 8.

Psychological: Somatization (2.5x), Depression (1.7x) and Anxiety (1.5x) were associated with delayed recovery.

Psychological symptoms appear to be a more worthwhile point of intervention than cognitive symptoms. Notably, fewer women were recovered (i.e., psychological symptoms) at week 8 relative to men. Strengths, limitations and future directions are discussed

### **19. The Relationship Between Objective Sleep Quality and Recovery Outcomes in Children and Youth Following Concussion**

M. Fisher, C. DeMatteo

Sleep quality problems are estimated to affect the majority of children following a concussion. Growing evidence suggests that poor sleep quality following a concussion

contributes to delayed recovery times, exacerbated symptoms, poor psychological outcomes, and negatively impacts quality of life. However, research regarding the relationship between postconcussion sleep quality and recovery outcomes in children is still sparse and inconsistent. As such, management of sleep problems post-injury are often not considered in concussion management strategies.

This study will seek to address: 1) what premorbid factors predict objective sleep quality outcomes in children after a concussion, 2) is sleep quality associated with the time to recovery after a concussion, and 3) is sleep quality associated with depression and quality of life outcomes.

As part of a larger longitudinal post- concussion study in youth, the sleep activity of 139 symptomatic children and youth (aged 5-18) with concussion were tracked using ActiGraph GT3X wrist accelerometers. Accelerometry measures of sleep were collected nightly throughout the course of participants' recovery through a stepwise Return to School/ Return to Activity protocol. Children completed the Post-Concussion Symptoms Scale every 48 hours and were evaluated at recruitment, at 1 month if still symptomatic and at three months post symptom resolution to assess outcomes of depression with the Child Depression Index-2 and Quality of Life with the KIDSCREEN-52.

Analyses are underway and demographics, results of predictive models and survival analysis using Cox regression will be presented.

## **20. Post-Concussion Syndrome and Sleep Abnormalities: A Retrospective Study**

A. Santos, H. Walsh, N. Anssari, I. Ferreira, M.C. Tartaglia

Patients with post-concussion syndrome (PCS) normally present with many symptoms including disturbed sleep and cognitive impairment.

We hypothesized that PCS patients have a higher prevalence of sleep abnormalities compared to the normal population and that sleep abnormalities are related to poor performance on neuropsychological testing and cognitive complaints.

A retrospective analysis of thirty-four patients with PCS who underwent a sleep study and neuropsychological testing with the Toronto Cognitive Assessment (TorCa) were included in this study. We evaluated the relationship between polysomnography data and neuropsychological tests.

There was a high prevalence of sleep apnea in the PCS patients (82.3%) compared to literature-derived prevalence in healthy population (6.40%). Decreased slow wave sleep was associated with more memory symptoms ( $r = -0.462$ ,  $p < 0.01$ ). Shorter duration of REM sleep was correlated with lower delayed recognition scores on the TorCA ( $r = 0.373$ ,  $p = 0.03$ ).

A high prevalence of sleep apnea was observed in this retrospective study of PCS patients. There was a relationship between sleep abnormalities and worse performance on memory tests. Poor sleep has been implicated in a number of PCS symptoms including headache, cognitive impairment, and mood issues. Addressing sleep abnormalities may help relieve some PCS symptoms.

## **21. Investigating the Ecological Validity of the Behavioural Assessment of Dysexecutive Syndrome (BADS) in Post-Acute Phase of Mild Traumatic Brain Injury**

E. Jeffay, K. Zakzanis

Small to moderate effect sizes have been reported between traditional neuropsychological test performance and return to work (RTW) status. The Behavioural Assessment of Dysexecutive Syndrome (BADS) was developed to measure executive functioning with the concept of verisimilitude in mind (tests that resemble real-world situations). There is some evidence that the BADS is more predictive of RTW status as compared to traditional neuropsychological test measures in patients who have had a TBI. However, the majority of these studies utilized moderate-severe TBI samples; little is known about the RTW predictive ability of the BADS and mTBI.

To determine the ecological validity of the BADS as compared to traditional neuropsychological test measures in a sample of patients who are beyond the three-month expected recovery period following a mTBI.

Methods: Using archival data, 102 patients were grouped into a binary outcome of employed ( $n = 30$ ) or unemployed ( $n = 72$ ). Mann-Whitney U comparisons were conducted between groups and Cohen's  $d$  was used to calculate effect sizes. A bonferroni correction was utilized.

Following the bonferroni correction, neither the BADS nor traditional neuropsychological tests could differentiate between RTW status. However, effect size analysis revealed a trend towards larger effect sizes for the BADS subtests as compared to traditional neuropsychological measures.

The BADS nor the traditional neuropsychological test measures significantly predicted employment status. However, medium-to-large effect sizes were found on the BADS subtests suggesting the potentially greater sensitivity of tests that are high in verisimilitude in predicting RTW status following a mTBI.

## **22. Supernormal Cerebrovascular Reactivity Following Acute Concussion**

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Concussion research has focused on examining neuronal disruptions post injury with little exploration on how injury may alter neurovascular coupling. Emerging evidence indicates that blood flow metrics could be more sensitive for detecting concussion than measures of neuronal integrity. Cerebrovascular reactivity (CVR) is defined as the change in cerebral blood flow per unit change in vasodilatory stimulus and is used to examine the integrity of autoregulation and neurovascular coupling. Our recent work has shown that CVR metrics including speed and magnitude of flow change to a standardized vasodilatory stimulus is constant across the adult age range. Deviations from this response could potentially be used for assessing individual subjects following concussion, given that blood flow dysregulation is known to occur following mild traumatic brain injury. Objective: To assess changes in CVR metrics (speed and magnitude of response) to a standardized vasodilatory stimulus during acute concussion.

12 concussed and 12 healthy controls (HC) underwent CVR assessment using Blood oxygen dependent MRI during precise changes in arterial Co<sub>2</sub> (RespirAct™). The amplitude and speed of response to the CO<sub>2</sub> stimulus were calculated in grey and white matter.

CVR magnitude was higher and speed of response faster in concussed participants relative to HC, with white matter showing greater responses than grey matter.

Our results are surprising in that we have never seen supernormal response to vasodilatory stimuli any other cerebrovascular disease. Our findings warrant further investigation comparing the predictive ability of CVR metrics against neuronal injury metrics for detecting acute concussion.