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Profiling position specific head trauma in professional American football based on impact magnitude and frequency

Clara Karton; Michael D. Gilchrist; Thomas Blaine Hoshizaki; MD

In American football repetitive brain trauma is associated with high risk of neurologic disorders. Head contact is integral to the game, resulting in high frequency of head contacts during a game/season. Low energy impacts that do not manifest signs recognized as injury still present metabolic and/or physiologic changes within the brain. The purpose was to estimate player position specific brain trauma profiles based on strain magnitude and impact frequency. Head impacts from 32 game films of professional football were documented and categorized based on event type, head location, and velocity for 8 positions. Inbound velocity was calculated using Kinovea 0.8.20 software. Events were reconstructed using 50th percentile Hybrid III headform, unbiased neckform, linear impactor (collisions) and monorail drop tower (falls). Maximum principal strain (MPS) within the cerebrum was calculated using UCDBTM. Frequency [$p < 0.0005$] and magnitude [$p < 0.0005$] were significantly different between the 8 positions. No significant differences in frequencies between the following; quarterback, wide receiver, and defensive back; running back, tight end, and linebacker; and between offensive and defensive linemen. Approximately 60% of documented impacts were received by linemen and tight end. The magnitudes of impacts experienced by quarterbacks were significantly different to all positions excluding wide receiver and defensive back. Wide receiver experienced significantly different magnitudes than both linemen; and differences were found between offensive linemen and defensive back. Approximately 95% of impacts experienced by linemen were below 17% MPS. Conversely, over 90% of impacts documented for quarterback were above moderate strain magnitudes (>17%). Results show risks of repetitive trauma and injury vary with position; some experience high frequency impacts of low magnitude while others receive lower hit counts of higher magnitudes. Findings showed that tight end and running back are particularly risky with relatively high brain strain magnitudes coupled with high frequency making them susceptible to high trauma loads.

Laboratory and on-field results of athlete head impact monitoring

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Background

Although concussion continues to be a major source of acute and chronic injury in automotive, athletic and military arenas, concussion injury mechanisms and risk functions are ill-defined. To overcome this knowledge gap, we have developed, tested and deployed a head impact monitoring mouthguard (IMM) system. The IMM system was first calibrated in 731 laboratory tests against Hybrid III and NOCSAE headforms with Reference kinematic sensors. Next, during on-field play involving n = 54 amateur American athletes in football and boxing, there were tens of thousands of kinematic signatures collected by the IMM. A total of 890 true positive head impacts were confirmed using a combination of signal processing and NINDS/NIH Common Data Elements methods [1].

Methods

Laboratory tests were conducted using an American football helmet (n = 451), padded headform (n = 99) or bare head (n = 181). The IMM included kinematics sensors, along with associated microprocessor, battery and data transmission. Peak linear acceleration (PLA) at headform center of gravity (cg) was compared in each test between Reference and IMM.54 athletes in football and boxing aged 11 to 22 were consented. Impact with cg PLA as low as 7 g were collected during practices/games.

Results/discussion

Laboratory data fit a linear model close to ideal y = x + 0, R2 = 1. There were >100,000 triggering events, with 890 true positives. "False positives" contained high frequency data not indicative of head motion. The median/99th percentile of (PLA) and (PAA) were 20/50 g, and 1700 rad/s2/4600 rad/s2. There were no diagnosed concussions. One athlete was removed by athletic training staff after a significant head impact.

Conclusions

In the future, head impact dynamics data must be correlated with sensitive and specific assessments of cognitive, executive, vision and balance parameters in order to determine the concussion assessment threshold.

In-season variations in head impact exposure among youth football players

Jillian Urban; Mirellie Kelley; Mark Espeland, PhD; Elizabeth Davenport; Christopher T. Whitlow; Alexander Powers; Joseph Maldjian; Joel Stitzel

Sport-related head impacts are of increasing concern as early evidence has demonstrated a relationship between subconcussive head impact exposure (HIE) experienced in contact sports, such as football, and changes in pre-to post-season imaging and cognitive measures. Cumulative HIE is often measured with a single number that amounts to the total exposure measured over the season and does not give any indication as to how the exposure was accumulated, nor how it varies during the season. Therefore, the objective of this study was to compare HIE during preseason, the first and second halves of the regular season, and playoffs in a sample of youth football players (n = 119, ages 9–13). Athletes were divided into 1 of 4 exposure groups based on quartiles computed from the distribution of risk-weighted cumulative exposure (RWECP). The mean 95th percentile linear and rotational accelerations and impacts per session in practices and games were compared across 4 exposure groups and time frames using mixed effects models. Within games, the sample mean 95th percentile linear and rotational accelerations ranged from 47.2 g and 2,331.3 rad/s^2 during preseason to 52.1 g and 2,533.4 rad/s^2 during the second half of regular season. Mean impacts per practice increased from preseason to the second half of regular season and declined into playoffs among all exposure groups; however, the variation between time frames was not greater than 2 impacts per practice. Time of season had a significant effect on mean 95th percentile linear and rotational acceleration in games (both $p = 0.01$) but not on practice accelerations or impacts/session. Mean 95th percentile accelerations for games showed significant interaction effects between exposure group and season segment (linear $p = 0.05$ and rotational $p = 0.04$). The results of this study improve our understanding of in-season variations in youth football HIE and may inform important opportunities for future interventions.

Head impact analysis in elite football (soccer)

Bianca Brigitte Rock; Thomas Blaine Hoshizaki, MD

Introduction

Trauma related neuropathologies including recent reports involving chronic traumatic encephalopathy (CTE) in 8 soccer players have been concerning. Purposeful sub-concussive head impacts, known as headers, are an integral part of the game. The purpose of this study was to describe dynamic head response and brain tissue strains for front ball-to-head impacts in elite soccer.

Methods

Video analysis thirteen (13) Champion's League soccer footage was completed to establish reconstruction parameters of head impact events. Analysis of 5 (5) front ball-to-head events were reconstructed using a Hybrid III 50th percentile headform and a pneumatic linear impactor. The University College Dublin Brain Trauma Model was used to calculate maximum principal strain (MPS).

Results and discussion

Recorded head impact velocities during elite soccer game play were 3.5–23.0 m/s. Most purposeful head-to-ball impacts occurred on the front-temporal region of the head (66.4%) at 0–15 degrees of cervical flexion. There was an average of 1.5 unintentional head impacts and 62.2 headers per game; 49.6% of headers occurred at an inbound velocity below 10 m/s. The lowest velocity reconstructed was 4.7 m/s, yielding 12.8 g and 604 rad/s^2 for peak resultant linear and rotational accelerations, respectively; the MPS for this impact was 0.09. Neurophysiologic changes and functional impairment have been reported in past research on sub-concussive impacts with 5%–15% strain. The mean 0.11 MPS yielded in this study reflects a potential for these changes in elite soccer athletes.

Conclusion

The main objective of this analysis was to identify impact characteristics and quantify dynamic cerebral response and brain tissue deformation in elite soccer game play. Further research must include cervical muscle activation, the level of play and player position, inbound ball-to-head velocities during different game play events and appropriate impact characteristics to appropriately characterize risk of injury in the attempts of mitigating risk of head injury during soccer game play.

Football concussion case series using biomechanical and video analysis

Mirellie Kelley; Jillian Urban; Derek Jones; Alexander Powers; Christopher T. Whitlow; Joseph Maldjian; Joel Stitzel

Approximately 1.1–1.9 million sport-related concussions among athletes ≤18 years of age occur annually in the United States, but there is limited understanding of the biomechanics and injury mechanisms associated with concussions among lower level football athletes. Therefore, the objective of this study was to combine biomechanical head impact data with video analysis to characterize youth and HS football concussion injury mechanisms. Head impact data were collected from athletes participating on 22 youth and 6 HS football teams between 2012 and 2017. Video was recorded, and head impact data were collected during all practices and games by instrumenting players with the Head Impact Telemetry (HIT) System. For each clinically diagnosed concussion, a video abstraction form was completed, which included questions concerning the context in which the injury occurred. Linear acceleration, rotational acceleration, and impact location were used to characterize the concussive event and each injured athlete's head impact exposure on the day of the concussion. A total of 9 (5 HS and 4 youth) concussions with biomechanics and video of the event were included in this study. The mean [range] linear and rotational acceleration of the concussive impacts were 62.9 [29.3–118.4] g and 3,056.7 [1,046.8–6,954.6] rad/s^2, respectively. Concussive impacts were the highest magnitude impacts for 6 players and in the top quartile of impacts for 3 players on the day of injury. Concussions occurred in both practices (N = 4) and games (N = 5). The most common injury contact surface was helmet-to-helmet (N = 5), followed by helmet-to-ground (N = 3) and helmet-to-body (N = 1). All injuries occurred during player-to-player contact scenarios, including tackling (N = 4), blocking (N = 4), and collision with other players (N = 1). The biomechanics and injury mechanisms of concussions varied among athletes in our study; however, concussive impacts were among the highest severity for each player and all concussions occurred as a result of player-to-player contact.

Comparing head impact kinematics simultaneously measured using 6 different sensors in a human cadaver model

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Objective

To compare head kinematics measurements obtained from 6 different head impact sensors utilizing different methods of sensor-to-head fixation.

Design

Free-drop impacts (total n = 54) were performed at 3.5 and 5.5 m/s onto to the front, back, side, and top of 2 elderly human cadaveric head-neck specimens: a helmeted (Riddell Revolution Speed) male specimen was dropped onto a NOCSAE testing pad; an un-helmeted female specimen was dropped onto a framed sample of field turf. The specimens were instrumented with an intracranial reference sensor surgically mounted at the approximate head center-of-mass by a rigidly-fixed custom standoff pad, an intra-oral test sensor rigidly fixed to the upper teeth/hard palate by a custom orthodontic appliance, and 4 commercially available head impact sensing systems: X-Patch, Vector mouth guard, HITS (helmeted condition only), and G-Force Tracker (affixed to helmet interior or head band depending on helmet status). Peak linear and rotational head accelerations (PLA and PRA) were compared between each sensor and the intracranial reference sensor using intraclass correlation coefficients (ICC [2, 1]).

Results

Agreement with reference PLA and PRA values differed between sensors, with the greatest agreement observed for the rigidly affixed intraoral sensor (ICC = 0.921, PLA; ICC = 0.810, PRA). Agreement for PLA and PRA, respectively, was: for X-Patch, ICC = 0.638, ICC = 0.155; for Vector mouth guard, ICC = 0.775, ICC = 0.480; for HITS, ICC = 0.662 (PLA only); for G-Force Tracker, ICC = 0.364 (PLA only).

Discussion

Head kinematics measurements during free-drop testing differed among sensors using different approaches of fixation to the head. There was greater agreement with intracranial reference PLA and PRA values for a rigidly affixed intraoral sensor utilizing an orthodontic appliance than for commercially available sensors incorporated into athletic equipment or otherwise non-rigidly affixed to the head. Measurement error attributable to non-rigid sensor-head coupling could potentially be reduced by incorporating an impact sensor into an orthodontic appliance in future research.

Biomechanical comparison of concussions with and without a loss of consciousness in elite American football

Janie Cournoyer; Thomas Blaine Hoshizaki, MD

Introduction

Loss of consciousness (LOC) occurs with approximately 8 percent of concussions in professional American football and has been associated with severity of injury (1, 2). However it is unknown how LOC relates to severity of head impact responses. The purpose of this study was to compare the head accelerations and brain tissue deformation between cases of concussions with and without LOC in elite American football to inform prevention strategies.

Methods

Concussive injuries with and without LOC from helmet-to-helmet and shoulder collisions as well as falls in elite American football were reconstructed in laboratory using hybrid III headform to obtain peak linear and rotational acceleration and maximum principal strain, cumulative strain damage at 10%, and strain rate metrics in 5 brain regions associated with loss of consciousness.

Results

Impact velocity, peak linear and rotational acceleration were greater in the LOC group than the no LOC group. The brain tissue deformation metrics were greater in the LOC group than the no LOC group. Linear acceleration was most predictive for cases of helmet-to-helmet collisions whereas shoulder collisions were best predicted by rotational acceleration. The best overall predictor was impact velocity.

Discussion/conclusion

The presence of a loss of consciousness in concussive impacts is a result of greater magnitude of brain tissue trauma. This was primarily caused by greater impact velocities in head impacts leading to LOC. Rules aiming at mitigating this aspect of the game would decrease the risk of a loss of consciousness in this sport. Each type of events resulted in different values of kinematic data and brain tissue deformation, which suggests that studies evaluating risk of concussions based 1 type of event cannot be generalized.

References

1. American Academy of Neurology. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. Neurology 1997;48:581–585.
2. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus Statement on concussion in sport—5th international conference on concussion in sport held in Berlin, October 2016. Br J Sports Med 2017;51:838–847.

A common data language for biomechanical devices used in TBI clinical research: The National Institute of Neurological Disorders and Stroke (NINDS) and Department of Defense (DoD) CDE recommendations

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Objective

The NINDS Common Data Element (CDE) project provides data standards for clinical research in neuroscience. NINDS/NIH and DoD collaborated to develop CDE recommendations for Biomechanical Devices in TBI. CDEs increase efficiency of clinical research studies by reducing study start-up time and cost, increasing data quality, facilitating data sharing and aggregation, and helping educate new clinical investigators.

Background

In January 2017, a working group (WG) of subject matter experts from academia, industry and the military convened to develop CDE recommendations for blast, blunt head impact and inertial-loading exposures measured by biomechanical devices. These CDEs are available as a subset of the TBI recommendations under the Disease/Injury Related Events Domain and Biomechanical Devices Sub-Domain on the NINDS CDE website.

Design/methods

The WG divided into 3 subgroups: Head Accelerometry, Impact Video and Blast Exposure to review commonly collected data and analysis methods. The Head Accelerometry subgroup focused on data captured by kinematic sensors in sports/activities. The Impact Video subgroup addressed the use of video information to confirm device measurements. The Blast Exposure subgroup compared data from research sources using blast overpressure sensors. Subgroup recommendations were reviewed internally across the WG before being posted for public review.

Results

The WG's end products are summaries, CDE metadata and template case report forms. Assigned classifications guide researchers in selecting CDEs: Supplemental-Highly Recommended (essential for specified conditions, study types or designs), Supplemental (commonly collected, but not required), and Exploratory (reasonable to use, but require further validation). Version 1.0 recommendations were made available for use through the NINDS CDE website in late February 2018.

Conclusion

These new CDE recommendations will facilitate robust metadata analysis and data-sharing. NINDS encourages use of CDEs for all clinical research in neuroscience. NINDS CDEs are a dynamic resource, which is updated periodically based on the current state of science.

Psychometric proprieties of a color-shape version of the switch task

Veronik Sicard; Alexe Simard; Robert Davis Moore; Gabriel Lavoie; Dave Ellemberg

The impact of concussions on an individual's cognitive functioning has become a growing health concern over the past several years; however, the search for sensitive tests persists. The task-switching paradigm is known to be sensitive to various medical conditions, including concussion. Accordingly, we developed 2 versions of the color-shape switch task. Three different costs are computed from the raw scores: global switch cost, which is thought to be a measure of global cognitive control; local switch cost, which is believed to be a measure of cognitive flexibility; and working memory cost. The aim of this study was to evaluate psychometric characteristics of these costs. An ANOVA revealed a main effect of sex on local latency switch cost, with females exhibiting longer latencies than males, $p = 0.05$. No main effect of sex was observed on any other switch costs. Moreover, no main effect of experimenter or version of the task was observed. Local switch cost was significantly correlated with trails 4 and 5 of the Comprehensive Trail Making Test ($rs > 0.21$, $ps < 0.04$). No other significant correlation between costs and established neuropsychological tests was observed, indicating low convergent validity. The intraclass correlation coefficient estimates ranged from 0.23 to 0.77, suggesting low-to-moderate 1-week test-retest reliability. Results indicated a low switch costs; convergent validity. Moreover, results show that the traditionally computed switch costs are less reliable than the primary outcomes (i.e., reaction time and accuracy). Researchers and clinicians should rely on primary variables from the task-switching paradigm rather than computing the traditional switch costs to increase the psychometric properties of the tasks which is critical to advances in theoretical models of executive functions and evaluations of clinical populations.

Measurement properties of the Dynavision D2 one-minute drill task in active adolescents

Tamara McLeod; R. Curtis Bay; Hannah Gray; Richelle Marie Williams

Objective
The purpose of this study was to evaluate test-retest reliability and practice effects of the Dynavision D2 in active adolescents.

Background
Following sport-related concussion, assessment of oculomotor function and vision is important. While clinical tests are recommended, computerized devices, such as the Dynavision D2, are emerging as viable tools for vision assessment. As with all concussion assessments, understanding test-retest reliability and susceptibility to practice effects is important for appropriate interpretation of serial assessments post-injury.

Design/methods
Participants included 20 female adolescents (age = 16.6 ± 1.10 years, mass = 62.0 ± 5.9 kg, height = 169.2 ± 5.1 cm). Participants completed 2 test sessions 1 week apart using the Dynavision D2. The Dynavision D2 includes a one-minute drill task where a single light illuminates, and participants hit the light as quickly as possible, completing 3 drills per trial. Participants completed 3 trials during the first session and 2 during the second. Independent variables were day (day 1, day 2) and drills (15 drills). Dependent variables were the number of hits per minute (Hits/min) and average reaction time (AvgRT). Within-day and between-day test-retest reliabilities were analyzed using two-way random effects intraclass correlation coefficients for consistency. Practice effects were analyzed with repeated measures analysis of variance and Helmert contrasts ($p = 0=.05$).

Results
Moderate-to-strong reliability was demonstrated for Hits/min (within-day 1 [ICC = 0.74; 95% CI: 0.53, 0.87]; within-day 2 [ICC = 0.91; 95% CI. 77.97]; between-days [ICC = 0.86; 95% CI. 65.95]). Moderate-to-strong reliability was demonstrated for AvgRT (within-day 1 [ICC = 0.70, 95% CI. 48.86], within-day 2 [ICC = 0.92; 95% CI. 78.97]; between-days [ICC = 0.85; 95% CI: 0.64.94]). Practice effects were noted for Hits/Min ($p = 0.001$) and AvgRT ($p < 0.001$). Helmert contrasts suggested that the practice effect plateaued at drill 11 for Hits/min and drill 12 for AvgRT.

Conclusions
Moderate-to-excellent test-retest reliability was found for the one-minute task drill with better reliability noted on day 2 and between days, compared to day 1. This task is susceptible to practice effects, highlighting the need for familiarization or practice trials prior to documenting patient scores.

Half of purposeful sandbaggers undetected by ImPACT's embedded invalidity indicators

Courtney Raab; Amy Peak

Objective
The primary objective of this study is to determine the ability of embedded invalidity indicators (EIIs) within the Immediate Postconcussion Assessment and Cognitive Test (ImPACT) to accurately identify individuals purposefully underperforming (sandbagging) on the baseline assessment. The secondary objective is to determine if any of the 5 specific EIIs are more or less likely to identify purposeful sandbaggers.

Background
Sandbagging baseline neuropsychological tests is a growing problem with significant potential consequences including premature post-concussion clearance.

Design/methods
Volunteers were recruited to complete a baseline ImPACT assessment. Participants were randomized to either a control group or a coached sandbagging group. Primary outcome measures were the number of participants identified as invalid via any EII, as well as mean raw composite scores and percentiles for each sub-section within the ImPACT assessment.

Results
Seventy-seven participants (37 control and 40 sandbaggers) completed the study. Only half (50%, n = 20) of the purposeful sandbaggers were identified via any EII. Appropriately, no participants in the control group were identified as invalid. The Working Memory EII correctly identified 40% of the purposeful sandbaggers, and the Three Letters EII identified 35% of purposeful sandbaggers. All other EIIs identified 15% of purposeful sandbaggers. Twenty-six purposeful sandbaggers achieved at least 1 composite sub-score, 1st percentile; 27% of those were not identified via any EII. One participant scored ≤ 1st percentile in every composite category and was not identified via any EII.

Conclusion
Sandbagging baseline ImPACT assessments without detection likely occurs more often than previous literature suggests. Half of purposeful sandbaggers were not identified via current EIIs, and 3 of 5 EIIs

identified 15% of purposeful sandbaggers. Re-evaluation or recalibration of ImPACT's current EIIs may be appropriate.

Evaluation of multisensory responses (oculomotor, vestibular, and reaction time) in 3, 8 and 15 days after mild traumatic brain injury

Alex Kiderman, PhD; Carey Balaban; Mikhaylo Szczupak; Hillary Snapp; Michael Hoffer

Background
Despite the prevalence of mild traumatic brain injury (mTBI, concussion) in a wide range of occupational, sport, and military settings, accurate diagnosis and optimal treatment of concussive injuries are delayed by several challenging obstacles. Ability to measure the multisensory functional integrity of numerous neuroanatomical pathways with multiple tasks (oculomotor, vestibular and reaction time) can capture impairments of brain function.

Methods
106 mTBI patients and 300 control subjects were tested in the vestibular labs at 2 military hospitals. Patients were tested 3 times at average 2.5, 8.5 and 15.8 days post-injury. All patients completed a health history questionnaire, a dizziness handicap index (DHI), a functional gait index (FGI), and Trail Making Tests (TMTs) and were assessed by a battery of tests with video-oculography (I-Portal VOG) comprised of a head mounted, high speed eye tracking system on a rotary chair device (I-Portal Neuro-Otologic Test Center). The individuals in the study performed multiple tests including saccades, antisaccade, pursuit tracking, nystagmus, optokinetic, vestibular motion, and reaction time.

Results
No single test was sufficiently predictive to have separation between controls and mTBI subjects but results from a computer controlled rotational head impulse test (crHIT), antisaccade and predictive saccade were highly correlated with mTBI for the first test session. Longitudinally, for example, 74% of patients in session 1, 56% in session 2% and 51% in session 3 had in crHIT gain or absolute asymmetry above 95% of the respective control's distribution.

Conclusion
These results suggest that vestibular, oculomotor and reaction time tests using can provide an objective and reliable method of capturing and quantifying abnormal response in patients with mTBI. In addition, this type of testing can be used to monitor the recovery process.

Effects on intracranial cerebral blood flow by history of concussion

Yu Hiramoto; Haruo Nakayama; Satoshi Iwabuchi

Aim
Decrease of intracranial cerebral blood flow is an important factor in pathophysiology of concussion. Transcranial Doppler (TCD) is simple and minimally invasive tool that can evaluate intracranial cerebral blood flow.

Method
We examined University American football players, number of 81 players. In the pre-season (before interpersonal contact), We evaluated their cerebral function with SCAT and evaluated intracranial cerebral blood flow with TCD by the same examiner. Forty-five players from which TCD waveforms could clearly be depicted were targeted. We divided them into concussion group (7 players with a history of concussion) and non-concussion group (38 players without a history of concussion). And we examined the score of SCAT and the parameter of TCD between the 2 groups.

Result
The average score of SCAT was 91.4 points, and there was no difference between the 2 groups due to the history of concussion. For parameter of TCD, the average of the depth is 64.9 mm, the average of Mean flow velocity is 37.4 cm/s (±9.2), the average of Peak flow velocity is 66.4 cm/s (±17.0). There was no difference between the 2 groups due to the history of concussion.

Conclusion
In this study, there was no significant difference in the parameter of TCD or SCAT due to the presence or absence of concussion history.

Concussion history and career status influence sports concussion assessment tool (SCAT-3) performance in elite football players

Brittani Cookinham; Chad Swank

Objective
To determine if concussion history and career status influences baseline Sports Concussion Assessment Tool (SCAT-3) performance in elite football players.

Design/methods
Fifty-seven elite football players (age 29.39 ± 7.49 years) categorized by career status (draft prospects, active professional players and retired professional players) underwent SCAT-3 assessments. The SCAT-3 was administered in accordance to published recommendations.[14] To examine our primary purpose, participants were placed into either a low concussion history (0–1 concussions) or multiple concussion history (2 + concussions) group. A Mann-Whitney U test was used to examine the differences of concussion history on SCAT-3 total symptoms, total symptom severity, SAC total scores, and m-BESS balance scores. To examine our secondary purpose, a Kruskal-Wallis test and a post-hoc analysis was used to analyze differences between career status categories.

Results
At baseline, common baseline symptoms were: fatigue (45.6%), trouble falling asleep (35.1%), difficulty remembering (33.3%) and irritability (22.8%); 36.8% reported no symptoms. The low concussion (0–1) group reported fewer symptoms (U = 608.50, $p = 0.001$), less symptom severity (U = 598.00, $p = 0.001$), and produced greater scores on the Standardized Assessment of Concussion (SAC) total scores compared to the multiple concussion (2+) group (U = 253.00, $p = 0.024$), but no differences were observed on modified Balance Error Scoring System (m-BESS) scores (U = 501.50, $p = 0.066$) on the Mann-Whitney U test. The Kruskal-Wallis Test and post-hoc analysis indicated retired players were significantly different from draft prospects and current professional players for total symptom scores ($p < 0.001$), total symptom severity ($p < 0.001$), SAC total scores ($p = 0.030$), and m-BESS ($p < 0.001$).

Conclusions
Concussion history and career status appear to influence performance on the SCAT-3 in elite football players. With this in mind, future research is recommended to determine normative scores on the SCAT-3 for elite football players.

Balance performance maintained during dual-task condition with a cognitive task across menstrual cycle

Meng Ni; Joseph Hazzard, Jr., EdD, ATC; Pamela Smith

Background

Dual-task, performing a balance task and a cognitive task simultaneously, has been used as sport-related concussion assessment tool. However, the effect of dual task on balance performance remains controversial. Also, the fluctuation of hormone across menstrual cycle on balance and dual-task performance has not been fully examined.

Objective

To examine (1) the effect of dual task on balance performance, (2) the interaction of female sex hormonal level, balance, and dual-task performance.

Design

A cohort study.

Setting

A laboratory of concussion research and services.

Participants

A group of 49 healthy female college-aged students (age = 21.6 ± 2.0 years).

Main outcome measures

The Stability Evaluation Test (SET) protocol, Balance error scoring system (BESS) test and postural sway velocity (deg/sec) by using VSR SPORT force plate. Three auditory mathematics questions were given for each condition of the SET test. Two single-task conditions were provided, including balance only and math only. Balance test and math questions were given simultaneously during the dual-task condition.

Results

There was no significantly statistically difference in BESS or sway velocity between single and dual task. However, the performance of math calculation is better in dual-task comparing to the single task (math only), with an 8%–12% higher rate of accuracy, but it didn't reach a statistical significance. The rate of accuracy during the dual task didn't vary among menstrual phases.

Conclusions

Balance performance was maintained under dual-task conditions and fluctuation of female sex hormones across the menstrual cycle may not affect working memory and executive function. These findings are potentially clinically applicable to detecting balance deficits and cognitive alterations in female concussed individuals. Future studies are needed to investigate the underlying mechanism of balance maintenance and attention dividend under dual-task conditions.

The influence of concussion knowledge on reporting intentions in collegiate student-athletes

Landon Bryce Lempke, ATC; Michelle Weber; Robert Lynall; Julianne Schmidt

Background

Concussion education programs have been implemented across sport associations to improve concussion recognition and reporting intentions. Despite widespread implementation, no studies have examined the influence of concussion knowledge on reporting intentions in collegiate athletes.

Purpose

To (1) examine if concussion knowledge is a predictor of concussion reporting intentions and (2) identify concussion knowledge differences based on sex, age, and years of sport eligibility remaining in collegiate athletes.

Methods

One-hundred five collegiate athletes across 3 universities completed an online reporting intentions survey (consisting of indirect and direct reporting intentions) and 2 online concussion knowledge surveys (indirect knowledge agreement and direct knowledge assessment [comprised of signs/symptoms recognition and general knowledge]) across a four-month period. General linear models were used to test whether concussion knowledge outcome scores predicted indirect and direct reporting intentions, and if concussion knowledge differed within demographic factors.

Results

Indirect knowledge agreement explained 12.9% of direct reporting intentions variability ($R2 = 0.129$, $F3, 73 = 3.61$, $p = 0.017$). Knowledge did not predict indirect reporting intentions ($p = 0.152$). Females demonstrated greater signs and symptoms recognition than males (females: 79.1% ± 12.3% vs males: 73.0% ± 13.5%, $p = 0.017$, d = 0.47). Knowledge outcomes did not differ between sexes ($p \geq 0.117$), age groups ($p \geq 0.491$), or years of eligibility remaining ($p \geq 0.393$). Neither age ($p \geq 0.491$) nor years of sport eligibility remaining ($p \geq 0.393$) affected concussion knowledge outcome measures.

Conclusions

Concussion knowledge has limited predictive capabilities for determining reporting intentions. Although statistically significant, concussion knowledge sex differences may not be clinically meaningful. Clinicians should take caution in relying heavily on knowledge interventions to influence concussion reporting. Future studies should examine the role psychosocial factors play in improving concussion reporting.

Sports-related concussion knowledge and attitudes of intramural and club sport athletes

Devon Freudenberger; Victoria Lucia

Introduction

Sports-related concussions have attracted greater public health concern as their incidence rises, leading to changes in concussion education and laws protecting athletes. Currently the intramural and club sport programs at Oakland University (OU) (Rochester, Michigan) do not have a concussion education program for its athletes. Therefore, determining the knowledge and attitudes these athletes have towards concussions is essential in determining whether a program is needed. We hypothesized that due to the lack of a concussion education program, athletes at OU do not possess adequate knowledge and harbor unhealthy attitudes towards concussions.

Methods

A validated, and reliable concussion knowledge and attitudes survey was identified, modified, and distributed to athletes participating in intramural and club sports at OU's Recreation Center. The responses were scored generating concussion knowledge and attitude scores. Data was analyzed using t-tests to evaluate significant differences between different groups.

Results

One hundred eight-two of 200 respondents had complete survey data, of which 53.6% were female and 46.4% male; 59.9% participated in

intramural sports only, 26.4% in club sports only, and 13.7% in both. The mean overall knowledge and attitude scores were 80.6% and 74.8%, respectively. These scores did not vary by sport participation ($p = 0.685$; $p = 0.51$). Female athletes had significantly higher knowledge than male athletes ($p = 0.011$). Athletes majoring in health science fields had significantly higher knowledge than athletes in non-health science majors ($p = 0.006$), but similar attitudes ($p = 0.697$).

Conclusions

While the results indicate that OU athletes possess some knowledge and generally healthy attitudes, there is room for improvement that could be met with a single concussion education program for both intramural and club sport athletes. Despite having significantly higher knowledge, health science athletes did not display healthier attitudes than non-health science athletes, suggesting that knowledge does not always confer healthier attitudes. Therefore, a concussion education program should emphasize improving athlete concussion attitudes.

Effect of contextual/procedure-based concussion education on community college student-athlete reporting of concussion

Nancy Chinn, EdD; Monica Ohkubo; Brianna Scott

Various measures have been recommended to facilitate early identification of concussion including concussion education. Most commonly, concussion education is provided via lecture, video, and written materials. The extent to which these modes of concussion education result in greater self-reporting of concussion by student-athletes is unclear. This retrospective study compared student-athlete concussion reporting behaviors of participants who received traditional concussion education with those who also received a contextual/procedure-based learning approach. Sports medicine charts were reviewed for 2 groups: collegiate student-athletes ($n = 301$) who received concussion education in the fall semester of 2015 in a classroom setting that included lecture, hand-outs and viewing a video (Traditional Learning Group) and collegiate student-athletes ($n = 271$) who received traditional education in the fall 2016 semester and additionally received contextual/procedure-based learning approach (Contextual/Procedure-based Learning Group). Data was analyzed using a series of t-tests. Percent of concussions identified increased by 42% when comparing the fall 2015 Traditional Learning Group to the fall 2016 Contextual/Procedure-based Learning Group. Self-reporting of concussion by student-athletes increased 69% in the Contextual/Procedure-based Learning Group. Time to report concussion was significantly lower for participants in the Contextual/Procedure-based Learning Group, but this result was specific only to male student-athletes. This study indicates a contextual/procedural-based learning approach to concussion education may positively influence reporting and reduce time to report when compared to a more traditional lecture-based approach to concussion education.

The stability of ImPACT baseline test performance over a 3-year period in high school athletes

Nicholas Erdman, AT; Samuel Walton, MEd; Jeremy Eith; Lizzie Leitch; Joanna Shutzer; Shari Norte; Munro Cullum, PhD; Jacob Resch, PhD

Purpose

Annual baseline assessment using computerized neurocognitive tests have been recommended by governing healthcare bodies for the management of sport-related concussion but is supported by limited evidence. The current study examined the stability of ImPACT performance across three-successive years in adolescent athletes.

Method

This prospective cohort included 229 (117 male, 112 female) high school student-athletes from 2 private high schools. ImPACT was administered in a controlled group setting (1–17 participants) at years 1 (T1; n = 229), 2 (T2; n = 101) and 3 (T3; n = 47). Repeated measures analyses of variance (ANOVA 4 × 3) were used to examine performance on ImPACT's Verbal Memory (VEM), Visual Memory (VIS), Visual Motor Speed (VMS), and Reaction Time (RT) composite scores. Paired t-tests were used for post-hoc analyses. Two-way mixed intraclass correlation coefficients (ICC [3,1]) with 95% confidence intervals (CI) were calculated between time points. Group mean and within-subject differences between each time point for ImPACT scores were analyzed using manufacturer provided reliable change indices (RCI). All analyses were performed with alpha = 0.05.

Results

A significant main effect was observed for VMS (F [2,92] = 27.90, $p = 0.001$) across time. Participants significantly improved on VMS between T2 and T1 (t [100] = 4.15, $p = 0.001$), T3 and T2 (t [46] = 7.19, $p = 0.001$), and T3 and T1 (t [46] = 3.85, $p < 0.001$). Weak (VEM: ICC = 0.37, CI = 0.19, 0.55) to strong (VMS: ICC = 0.83, CI = 0.74, 0.90) ICCs were observed for ImPACT scores. No group mean differences exceeded the 80% CI for ImPACT's RCI, although within-subject differences for at least 1 score exceeded the 80% CI between T2 and T1 (24%–39%), T3 and T2 (26%–45%), and T3 and T1 (32%–51%).

Conclusions

Overall, statistically significant improvement was observed for VMS, however, the magnitude of the change may not be clinically meaningful. Similar to previous research, reliability of ImPACT scores ranged from weak to strong. Our results support annual baseline assessment of young athletes for progression of neurocognitive functioning.

Return to play following a sports concussion: The "added value" of post-exertion assessment

Veronik Sicard; Jean-Christophe Lortie; Robert Davis Moore; Dave Ellemberg

Decision of return to play (RTP) after a concussion is critical given the potential consequences of premature RTP. Athletes should not be cleared for full contact activity until they demonstrate normal cognitive functioning on both rest and post-exertion assessments. Accordingly, this study aimed to examine post-exertion cognitive performance in asymptomatic collegiate athletes who were cleared to return-to-play. Twenty-two recently concussed athletes who completed step 4 of Zurich's RTP protocol and 39 teammate controls participated in the study. They completed a Switch task before and after an acute bout of moderate cardiovascular exercise (80%–85% maximal predicted maximal heart rate for 20-minute) on an ergocycle. Based on their performance on both conditions (Rest, Post-exertion), concussed athletes were categorized into the Pass or Fail group. Specifically, they were placed in the Fail group if their performance was 2 SD lower than the control group's average score. A χ^2 test was used to test for equality of proportions between conditions. Although, the proportion of athletes categorized in the Fail group was higher in post-exercise (31.82%) relative to rest (22.73%), it did not reach statistical significance ($\chi^2 = 0.20$, $p = 0.66$). Irrespective of condition, 45% of concussed athletes were categorized in the Fail group. Of these, 10% failed on both conditions, 13% failed on rest only, and 22% failed on post-exercise. The current study suggests that 1 out of 2 athletes who successfully completed the

RTP protocol exhibited diminished cognitive functions compared to controls. The use of a sensitive cognitive test, combined with physical exertion, can prevent premature RTP in identifying athletes would have otherwise received medical clearance.

Gender differences in transcranial doppler ultrasound measured features and self-reported symptoms after sports-related concussion

Corey Thibeault, PhD; Samuel Thorpe, PhD; Nicolas Canac; Mina Ranjbaran; Michael O'Brien; James LeVangie; Mateo Scheidt; Seth Wilk; Robert Hamilton, PhD

The possibility of gender-related differences in concussion severity and recovery remains a controversial subject. With some studies showing that female subjects suffer a longer period of symptom recovery as compared to males, while other studies have failed to demonstrate significant differences. In this retrospective study, we explored the gender-related effects of concussion on both self-reported symptoms and physiologic features (captured with TCD) that were previously shown to be related to concussion. A total of 75 subjects, with a mean age of 16.2 years (1.16), consisting of 51 males and 24 females, were assessed—at different points post-injury—after suffering a clinically diagnosed sports-related concussion. Subjects first answered a series of symptom related questions based on an integer rating scale. The velocity from the middle cerebral artery (MCA) was insonated bilaterally through transtemporal windows with TCD. After a baseline period, subjects participated in 4 breath-holding challenges. The Pulsatility Index (PI) was computed from the baseline section, while the Breath Hold Index (BHI) was computed from the challenge sections. Over the first 10 days post-injury, the female subjects had significantly higher symptom scores. In addition, the length of recovery was longer, lasting 14 days compared to 9 days, before the overall mean symptom score returned to baseline; The BHI and PI were not significantly different between genders. The elevated symptom scores for the female subjects without a significant correlation to physiologic measurements is possibly due to reporting bias. The population consisted of high school aged athletes who were motivated to return to play, perhaps explaining why the male population reported lower symptom severity than the female population. However, the potential of increased severity in the female population cannot be overlooked. This pilot study illustrates the need for more focused research on gender differences in concussion pathophysiology.

Gender differences in quantitative EEG volumetric analysis shortly after sport concussion injury in high school athletes

Harry G. Kerasidis, MD; P. David Ims; Stacie Rector

Background
Studies have identified gender differences in the incidence, severity and recovery time from sport concussion injury, all increased in females. The objective of this investigation is to explore gender differences in volumetric QEEG analysis after sport concussion injury in high school athletes.

Methods
Standard electroencephalograms (EEGs) were analyzed in 40 high school athletes (20 males) shortly after concussion injury using sLORETA imaging compared to a normative database (NYU/BrainDx). Peak Z-score variation (PZV), and %volume of grey matter activity that fell outside Z = −2.5 to 2.5 (PIGMV for increased activity, PRGMV for reduced) were calculated for each of 5 EEG frequency bands.

Results
PZV was increased in the Delta/Theta/Alpha, in both genders with no statistical gender difference (M/F averages: 3.82/3.16, 2.73/2.72, 2.52/2.72, respectively, $p \geq 0.05$), Beta in females not males, Beta-Gamma in males and females which was significantly increased in females (M/F averages: 1.75/2.88, 3.64/5.02 respectively, $p < 0.01$). PZV was decreased in Beta in males not females (M/F averages: −2.83/−2.18, $p = 0.05$) there was a significant difference in reduced beta-gamma activity (M/F averages: −1.11/−0.49, $p = 0.01$). Greater than 1% grey matter volume of PIGMV was seen in Delta/Theta/Alpha/Beta activity with no gender difference (M/F averages: 20.94/11.71, 5.87/7.38, 5.62/7.93, 4.09/9.22 $p \geq 0.05$). There was a significant difference in PIGMV in Beta-Gamma (M/F averages: 31.94/60.04, $p = 0.01$). Greater than 1% PRGMV in Alpha/Beta in both genders and Theta activity in females not males.

Conclusions
Slower frequency (Delta, Theta, and Alpha) abnormal variations show no statistical gender differences. In the faster frequency bands (Beta and Beta-Gamma), females demonstrate a larger variation from the norm and larger percent grey matter volume affected by increased Beta and Beta-Gamma activity. Males, not females exhibit a deficiency in Beta activity after concussion. Further research to correlate these electrophysiologic changes with symptom severity and recovery time is needed.

The epidemiology of sport related concussion in Brazilian Jiu-Jitsu

Matthew Spano; Mill Etienne, MD, MPH, FAAN

Brazilian Jiu-Jitsu (BJJ) is a rapidly growing grappling sport with a wide spectrum of participants. This study aimed to analyze the prevalence of concussions among BJJ practitioners while determining potential predictive factors. A 17-question survey was distributed via email to BJJ practitioners in the United States. The survey included questions on practitioners; demographics and the development of a concussion doing BJJ. Among those with a concussion during BJJ, further information was elucidated on symptoms, return to play, and the development of a second concussion. A total of 780 survey responses were analyzed, ranging in age from 18 to 67 with females representing 11.8% of respondents. 25.2% of practitioners reported a concussion doing BJJ. Forty-three percent of females reported a concussion doing BJJ compared to 22.9% of males (X2 [1, n = 740] = 15.129, $p = < 0.001$). This gender difference did not exist in the prevalence of concussions before starting BJJ (X2 [1, n = 774] = 1.930, $p = 0.381$). Logistic regression indicated several factors predictive for developing a concussion from participating in BJJ including: having a prior concussion (odds-ratio = 1.691, $p = 0.017$, 95% CI 1.097, 2.606), the number of competitions in which an athlete participated (odds-ratio = 1.023, $p = 0.016$, 95% CI 1.004, 1.042), and

female gender (odds-ratio = 1.863, p = 0.048, 95% CI 1.006, 3.450). Logistic regression indicated competing more times per year was predictive for developing a second concussion [odds-ratio = 1.038, p = 0.016). After a concussion, the median time to return to BJJ was 3 days. This included 30.8% of participants returning the day of their concussion. The present study represents the first epidemiologic research examining concussions in Brazilian Jiu-Jitsu. The results underscore the need for increased education on concussions and return to play guidelines among BJJ coaches and practitioners.

Disclosures: Dr. Spano has nothing to disclose. Dr. Etienne has nothing to disclose.

Incidence of head injury and concussion among synchronized skaters: Rates, risks, and behaviors

Gretchen Mohney; Robert Baker; Shelly DiCesaro

Data regarding risk and rates for head injury and concussion specific to the sport of synchronized skating is absent from literature. This study differentiated team level-based rate and risk for head injury and concussion, identified behaviors to include education, baseline screening and protective equipment utilization, and the implementation of return to play protocols. An anonymous cross-sectional survey was implemented at the 2018 U.S. Synchronized Skating Championships. Participants were female members of a qualifying team, ages 13 and older, intermediate participation level and higher. The survey response rate was 42% (520/1,232). Among the survey respondents, 7% (36/520) reported head injury in the practice setting and 1% (4/520) in the competitive setting. Among respondents who reported head injury (n = 37), 68% (25/37) reported a team skill injury, with senior level reporting the highest 22% (13/75) rate. Among the sample population (n = 520), the odds of sustaining a head injury during a team skill was 2.13 times more likely than during individual skill (OR: 2.13, CI: 1.06, 4.30; p = 0.03). The odds of sustaining a head injury during practice was 9.59 times higher than in competition (OR: 9.59, CI: 3.30, 27.15; p < 0.0001). Among the sample population, 36% (188/520) reported receiving concussion education during the past training year and 8% (44/520) reported hitting their head on the ice and returning to skating without seeking medical consultation. A χ^2 analysis did not reveal a significant association between education and return to skating without medical consultation X2 (1, n = 520) = 0.391, p = 0.532. Baseline screening was reported among 25% (128/520) of the survey respondents. Only 0.06% (3/520) of the survey respondents reported utilizing protective headgear. Among those reporting concussion (n = 26), 92% reported receiving a return to sport/learn progression. Emphasis on concussion education and medical provider access should be targeted to team skill development in the practice setting.

Disclosures: Dr. Mohney has nothing to disclose. Dr. Baker has nothing to disclose. Dr. DiCesaro has nothing to disclose.

Altered state of consciousness in mild traumatic brain injury in relation to utilization of services

Sam Meske, MS; Joseph Hazzard, Jr., EdD, ATC; Meng Ni

Introduction
Prevalence of traumatic brain injuries (TBI) in young adults on college campuses worldwide is extremely concerning, given that this age range is critical for cognitive and behavioral development. Impaired cognition can negatively affect academic performance and quality of life, while the prevalence of acute and/or chronic symptoms impact outcome measures of intellectual efficiency and mental health. It has been reported that a greater number of TBI symptoms and altered state of consciousness are correlated with more academic challenges, chronic symptom prevalence, long-term deficits in executive, emotional, and behavioral functions, and lower employment outcome.

Objective
(1) Determine the relationship between altered or loss of consciousness and utilization of services. (2) Compare gender differences in prevalence of altered state of consciousness and service utilization from TBI.

Methods
A campus wide email was sent out, with a Qualtrics online survey asking questions that pertained to the participants' TBI history, state of consciousness immediately following the injury, symptom prevalence, and the campus services they utilized.

Results
Of 194 respondents included in analysis, 36.6% indicated a loss of consciousness and 35.6% altered consciousness from TBI. At the same notion, only 9% of respondents indicated utilizing services. Interestingly, frequency of respondents' who accessed services was lower for those who experienced only loss of consciousness or both loss and altered consciousness, and higher for those who experienced only altered consciousness or neither (2.7%, 8.6%, 29.4%, 9.1%, respectively). No significant differences were observed between genders for altered state of consciousness or services utilized. However, more men seemed to indicate that they experienced neither change in consciousness (58.8% compared to 39.8% of females).

Conclusions
State of consciousness may not be a good predictor of subsequent service utilization. Additionally, gender differences do not seem apparent when analyzing service utilization or level of consciousness at time of injury.

Disclosures: Dr. Meske has nothing to disclose. Dr. Hazzard has nothing to disclose. Dr. Ni has nothing to disclose.

The influence of concussion on cardio-autonomic function during cognition before and after exercise

Adam T. Harrison; Brett Steven Gunn; Jacob James Michael Kay, MS; Robert Davis Moore

In an average day of a student-athlete, they must endure the cognitive demand of classes, physical stress of practice, and then end the day studying and doing homework for the next day. Cardio-autonomic regulation is an integral process linking the neurologic and cardiological systems, that responds and adapts to these changing environmental stressors to maintain overall effective functioning. The adaptation of the cardio-autonomic system to environmental stressors is often impaired in people who have experienced a concussion. The aim of the current study, was to assess cardio-autonomic function in a group of athletes with and without a history of sports-related concussion (SRC) in an experimental paradigm designed to mimic an average day of a student-athlete. Heart-rate variability (HRV) was assessed in a group of adolescent athletes with a history of diagnosed concussion (n = 16) and healthy matched controls (n = 19) (1) at rest; (2) during a switch task paradigm; and (3) during a switch task paradigm following a 20-minute bout of aerobic exercise at ~70% of their theoretical max heart rate. Results of the preliminary investigation revealed that individuals with a history of SRC exhibited alterations in HRV at rest, that were exacerbated by the cognitive load of the switch task. However, following the bout of aerobic exercise, HRV normalized in the individuals with a history of SRC. These results continue to demonstrate cardio-autonomic dysregulation following a SRC. It also indicates the potential therapeutic benefit of aerobic exercise in mediating these cardio-autonomic abnormalities.

Disclosures: Dr. Harrison has nothing to disclose. Dr. Gunn has nothing to disclose. Dr. Kay has nothing to disclose. Dr. Moore has nothing to disclose.

The clinical utility of using involuntary eye movements to assess concussion

Kathleen Heeter; Thayer Jacob; Nicholas Port

Critical decisions are made daily about whether to bench athletes who might have suffered a concussion or mild traumatic brain injury (mTBI). The low-level damage underlying mTBI has been difficult to measure, especially during competition when assessments are made quickly utilizing primarily subjective symptoms. The ideal instrument would be (1) sensitive to low-level diffuse damage, (2) easily and rapidly administered on the sidelines, and (3) unaffected by human bias or sandbagged baselines. Based on a body of research documenting the sensitivity of oculomotor movements (e.g., saccades and smooth pursuits) to mTBI damage, we have constructed 5 Sideline Eye Trackers and are evaluating their clinical use for quick, objective and accurate assessment of mTBI. Current enrollment of athletes is over 1,200, including the entire IU athletic department and several local schools. All enrollees complete a 6-minute, pre-season, baseline oculomotor exam consisting of 2 saccade, 2 pursuit, and 1 ocular following task. Balance is simultaneously measured using a portable balance board. Anyone suspected by the team physician of having a concussion during the season repeats this exam 3 additional times: (1) immediately post-injury (minutes), (2) at the time of being cleared for return-to-play, and (3) as far post-injury as possible (months). To provide 2 separate measures of test-retest variability, 2 control groups are also being studied: (1) within-sport non-concussed matched control group, and (2) non-concussion prone cross-country athletes. Athletes with mTBI show significant deficits in both saccadic and pursuit function compared to their baseline ($p = 0.0001$). Drift in the center of pressure measure (balance) is also significantly affected in many subjects. Signal detection theory yields a specificity & sensitivity of greater than 85% of 69 concussed athletes. Measuring oculomotor dysfunction in athletes with a 6-minute task may be a promising tool for the diagnosis and management of mTBI.

Disclosures: Dr. Heeter has nothing to disclose. Dr. Jacob has nothing to disclose. Dr. Port has nothing to disclose.

Symptom free return to sport following supervised exercise and a return to play progression

Matthew T. Lorincz, MD, PhD; Melvin Darwin; Andrea Almeida, MD; Andrew R. Sas, MD, PhD

Objective

To determine if completion of a symptom free return to play progression (RTPP) was associated with a symptom free return to sport. A secondary analysis investigated symptom free return to sports participation following supervised exercise.

Background

The current consensus statement on concussion in sport recommends a graded return-to-sport strategy but there is limited data on the utility of this approach.

Methods

200 sequential clinic patients with physician-diagnosed concussion sustained during sport participation were contacted by phone following completion of care from a University-associated Sports Neurology clinic. A survey about their success in returning to their sport was administered. Standardized data elements were extracted from the medical records and analyzed. The study was approved by the university of Michigan Institutional Review Board.

Results

The survey was completed on 61 (31%) patients. Of these, 57 (93%) returned to sport participation without symptom reoccurrence. Of those who returned to sport 41 (80%) returned to sport without symptom reoccurrence within 2 weeks of completed clinical care. 53 (87%) completed a RTPP and 49 (92%) of those completing a RTPP returned to sport without symptom reoccurrence. Completing a RTPP, compared to those not completing a RTPP, was significantly associated with return to sport participation without symptom reoccurrence ($p = 0.0000001$). Of those surveyed, 32 (52%) underwent supervised exercise (SE) as part of their clinical care. Completing SE, as compared to those not undergoing SE, was significantly associated with return to sport participation without symptom reoccurrence ($p = 0.017$).

Conclusions

Our results support recommendations for utilizing graded return-to-sport strategy demonstrating that 92% of those completing a RTPP successfully returned to sport. Our data also suggest that completion of SE was a predictor of symptom free return to sport and can be incorporated in to return to play decision making.

Disclosures: Dr. Lorincz has nothing to disclose. Dr. Darwin has nothing to disclose. Dr. Almeida has nothing to disclose. Dr. Sas has nothing to disclose.

Quantitative pupillary light reflex abnormalities in acute concussion

Melissa M. Cortez, DO; Asad Raud

Background

The process of concussion diagnosis following a sports injury remains suboptimal, and currently relies on self-reported symptoms and/or diagnostic "task-based" assessments with subjective and effort-based limitations. The purpose of this study was to evaluate the use of pupillometry light reflex (PLR) as a potential objective physiologic marker in concussion.

Methods

Six (6) subjects underwent baseline (pre-concussion) PLR testing using a Neuroptics, DP-2000 Binocular Pupillometer. Pupil diameter was recorded for 5 seconds following a brief light stimulus in a single eye. The following values were obtained from the recordings in both the stimulated and consensual eyes: maximum diameter, minimum diameter, percent change, latency, constriction velocity (CV), maximum constriction velocity (MCV), dilation velocity (DV), T75, and RA5. T75 and RA5 represent the time to 75% re-dilation and the re-dilation amplitude from baseline, respectively. Measurements were taken again within 48 hours of concussion, in the same participants. A paired, 2 tailed t-test was used to assess significant changes in these values. Bonferroni correction was applied to account for multiple comparisons.

Results

RA5, a measure of pupillary sympathetic function, was significantly reduced ($p = 0.004$) in the post-concussive state compared to pre-concussion baseline. Additionally, percent change, a measure of pupillary parasympathetic function, was greater post-concussion compared to baseline, though this did not meet significance following Bonferroni correction ($p = 0.007$). A similar pattern was seen in the consensual eye, though these differences did not meet significance.

Conclusions

We demonstrate significant changes in pupillary autonomic function within 48 hours of a concussion. These findings support the potential use of PLR as a biomarker in athletes following concussion, with the potential to yield important mechanistic information about the acute concussive state.

Disclosures: Dr. Cortez has nothing to disclose. Dr. Raud has nothing to disclose.

Psycho-affective health, cognition and neurophysiological function following sports-related concussion in symptomatic and asymptomatic athletes

Adam T. Harrison; Veronik Sicard; Robert Davis Moore

The proposed normal recovery window for a concussive-injury is 10–14 days. However, a significant portion of athletes who sustain a sports-related concussion (SRC) exhibit symptoms beyond this recovery window. Little is known about the neuropsychiatric and neurophysiologic differences within these slow-to-recover athletes, that may explain these prolonged recovery periods. The present study aimed to investigate the psycho-affective and neuropsychological profiles of symptomatic and asymptomatic athletes who recently experienced an SRC. Additionally, we compared these concussed athletes with healthy controls, without a history of concussion. Accordingly, 78 participants with a history of concussion (26 Symptomatic, 26 Asymptomatic) and 26 healthy controls completed a neuropsychiatric and neuropsychological test battery; including the Beck's Depression Index (BDI II), Profile of Mood States (POMS), and 2-Back task. Additionally, event-related brain potentials (ERPs) were recorded during an experimental oddball paradigm. The results suggest that symptomatic athletes report significantly worse levels of depressive symptoms and negatively altered mood, compared to both asymptomatic and control athletes. Additionally, symptomatic athletes demonstrated poorer performance on the 2-back test, characterized by increased commission errors and slower reaction times. Finally, ERP analyses revealed that both symptomatic and asymptomatic athletes demonstrated reduced allocation of attentional resources during the oddball task, indexed by reduced P3b amplitude. However, only asymptomatic athletes exhibited prolonged P3 latency indicative of delayed information processing. Taken together these results suggest that compared to asymptomatic and healthy athletes, athletes with persistent concussive-like symptoms not only report greater disruptions in affect and mood, but also demonstrate impaired cognitive and neurophysiologic function.

Disclosures: Dr. Harrison has nothing to disclose. Dr. Sicard has nothing to disclose. Dr. Moore has nothing to disclose.

Photophobia symptoms and visual pain thresholds in posttraumatic headache after mild traumatic brain injury

Nicholas Jarvis; Amaal J. Starling, MD; Todd J. Schwedt, MD, FAAN

Background

Light sensitivity can be a disabling symptom in posttraumatic headache (PTH). The objective of this pilot study was to characterize photophobia symptoms and visual pain thresholds in PTH compared to healthy controls (HC).

Methods

Individuals with PTH attributed to mild traumatic brain injury (mTBI) (N = 18) and HC (N = 20), aged 18–65, were prospectively assessed using the Photosensitivity Assessment Questionnaire (PAQ), State Trait Anxiety Inventory (STAI), and Beck Depression Inventory (BDI). A progressive light stimulation device was used to quantify visual pain thresholds. Visual pain thresholds were determined by the intensity of light at which subjects first noted pain. The mean of 3 trials was considered the visual pain threshold. Two sample t-test, Wilcoxon rank sum test, χ^2 test and Fisher exact test was used to compare the 2 groups for their demographics, clinical characteristics, and outcomes measures.

Results

There were no differences in demographics including age, gender, or race. The average time since onset of PTH was 50.7 (73.6) months. Those with PTH had 15.8 (9.2) headache days per month. BDI and STAI scores were significantly higher in PTH compared to HC.

Photophobia was higher in PTH compared to HC, 0.64 (0.25) vs 0.24 (0.24), $p < 0.0001$. Visual pain thresholds were lower in PTH (median 50.1 lux; quartiles 15.3 to 300.0) compared to HC (median 863.5 lux; quartiles 519.9 to 4,906.5; $p = 0.0002$).

Conclusion

Photophobia symptoms are higher and visual pain thresholds are lower in PTH compared to HC. Light sensitivity is a well-known disabling symptom in PTH and this pilot study provides objective data through a validated photophobia scale and visual pain thresholds to characterize light sensitivity. Additional studies are needed to confirm this data, to compare acute to persistent PTH, to compare PTH to other headache disorders, and to determine if photophobia and visual pain thresholds will improve with intervention.

Disclosures: Dr. Jarvis has nothing to disclose. Dr. Starling has received personal compensation for consulting, serving on a scientific advisory board, speaking, or other activities with Eli Lilly & Company, eNeura, Alder, and Amgen. Dr. Schwedt has received personal compensation for consulting, serving on a scientific advisory board, speaking, or other activities with Allergan, Amgen, ATI, Avanir, Dr. Reddy's, Nocira, Novartis, Teva. Dr. Schwedt has received personal compensation in an editorial capacity for Headache, Pain Medicine, Cephalalgia.

Pediatric headache incidence and outcomes after sports-related concussion: Findings from the North Texas ConcussionRegistry (ConTex)

Bert B. Vargas, MD, FAAN; Elida Godbey; Stephen Bunt; Ali Shah Tejani; Munro Cullum, PhD

Introduction

Headache is the most common symptom reported after concussion; however, little is known about the incidence of headache and the clinical course over 3 months in pediatric patients with sports-related concussion (SRC) presenting within 30 days of injury.

Methods

Four hundred twenty-five patients met inclusion criteria (patients under 18 years old limited to SRC within 30 days of injury and who also completed a 3 months follow up evaluation) and were enrolled from any 1 of 5 ConTex clinic sites.

Results

Mean age was 14.3 years (range = 7–18, SD 2.2) and mean time since injury at presentation to clinic was 8.1 days (range = 0–30, SD = 6.7). Only 13.7% (n = 56) had a history of headache before their concussion. 96.5% (n = 410) of patients recalled having headache at time of injury. At initial presentation, 77.3% (n = 317) reported headache; 38.2% (n = 121) mild, 48.6% (n = 154) moderate, 13.2% (n = 42) severe (on a scale from 0-6). At 3 months follow up, 19.8% (n = 81) reported headache; 76.6% (n = 62) mild, 18.5% (n = 15) moderate, 4.9% (n = 4) severe. Among 264 that were treated with headache abortive medications, 97.7% (n = 258) used simple analgesics (NSAIDs or acetaminophen); 0.8% (n = 2) used opioids; 10.2% (n = 27) used triptans; and 5.7% (n = 15) used other non-specified treatments. 66.5% of children reported symptom resolution within 29 days (range 0–90 days, mode 17–29, n = 71, 20.2%).

Conclusions

The incidence of headache at the time of concussion is high and remains high within 30 days after injury, the majority of which were moderate in severity. By 3 months, only a minority of patients report headache, the majority of which were mild. For 86.3% of children, their first experience with recurrent headache occurred in the context of SRC. Outcomes were generally good at 3 months despite an overwhelming majority of children being treated with non-specific, simple

analgesics. Most children reported symptom resolution within 29 days of injury.

Comparing the acute presentation of sport-related concussion in the adult and pediatric populations

Sandro James Corti, MD; Nicole Pizzimenti; Matthew T. McCarthy, MD; Kate M. Essad, MD; Jeffrey S. Kutcher, MD, FAAN

Introduction
Despite growing research on concussion, there is currently minimal evidence comparing the acute presentation of sport-related concussion between adult and pediatric patients.

Objective
To assess and compare the injury characteristics, symptoms and neurologic exam findings in acute sport-related concussion between adult and pediatric patients.

Methods
Retrospective cohort study of all patients presenting to an outpatient sports neurology clinic for initial assessment of an acute concussion within 7 days of injury between January 2016 and August 2017. Patients were divided into 2 groups, 18 and older (n = 28) and 17 and younger (n = 107). Data assessed included age, sex, injury date, date of visit, injury characteristics, Sport Concussion Assessment Tool (SCAT3) symptom scale, sleep characteristics, comorbid medical diagnoses, and neurologic exam findings.

Results
There were no significant differences between the adult and pediatric patients in any SCAT3 symptom score, neurologic exam category, pertinent elements of past medical history, or characteristics of the acute concussion, including number of head impacts, presence of helmet, loss of consciousness, amnesia, or continuation of play. The pediatric group had significantly higher average hours of sleep ($p = 0.034$) and were less likely to wake up refreshed ($p = 0.024$). There were no other significant differences in sleep characteristics between the groups.

Conclusions
The initial presentation of acute concussion within 7 days of injury will likely not differ by age, specifically 18 and older vs 17 and younger. These data suggest no indication for focusing on specific portions of the history or neurologic examination based on these age groups.

Baseline concussion symptom score differences comparing collision, contact, and noncontact sports and comparison of between sexes

Andrew Sas, MD, PhD; Katherine Foug; Aleah Gillenkirk; Michael Popovich, MD; Andrea Almedia, MD; Matthew Lorincz, MD

Objective
To determine if baseline concussion symptoms scores in athletes prior to the start of their season vary by sport or sex.

Background
Concussion is a clinical diagnosis that includes an appropriate clinical scenario, reporting of symptoms through a post concussion symptom score list, and an objective neurologic exam. Symptom reporting is considered when determining if an athlete has recovered from their concussion. Recent studies have shown that athletes at baseline can report symptoms at a rate high enough to meet criteria for post concussion syndrome without any history of concussion. The number of symptoms reported was found to be higher in female athletes than male athletes, but to date there has not been a clear consideration of how these symptoms compare across different sports played.

Methods
Retrospective chart review of baseline pre-participation sport exams from 2016. More than 2000 charts were reviewed for age, sex, sport played, number of past concussions. Baseline concussion symptom checklist scores were reviewed for number of symptoms reported and severity of symptoms reported. Comparisons were made between groups comparing age, sex, sport played, and number of previous concussions prior to the start of this season.

Results
Female athletes in all sports compared reported more baseline symptoms and more severe symptoms compared to their male counterparts. Athletes of the same sex, male or female who participated in collision or contact sports reported less baseline symptoms than athletes who participated in noncontact sports.

Conclusion
Contact and collision sport athletes report at baseline less concussion checklist symptoms than noncontact sport athletes in all age groups compared. This leads to many questions about why certain athlete populations report less symptoms. Symptom reporting could be due to underlying physical traits in different sports, or player psychology differences between sports.

A single season of soccer results in no significant neurophysiological changes in adolescent female athletes

Kaylin Ryan; Katherine Schiller; Roozbeh Rezaie; Brandon C. Baughman; Shalini Narayana

Introduction
Sports related mild traumatic brain injury (mTBI) is a serious and increasing health incident in the United States, particularly in young children and adolescents, often affecting developing frontal and temporal lobes. Literature comparing various methods of cognitive assessment tools as well as the utility of various non-invasive brain imaging technologies in the diagnosis and follow up of mTBI lacks standardized methods and requires further investigation. We investigated the stability of intercortical and intracortical inhibition parameters and their relationship to white matter integrity, in athletes without mTBI. We hypothesized that a single season of soccer, without a concussion, would result in no significant neurophysiologic differences, in female adolescents.

Methods
Ten female soccer athletes, between the ages of 14–17 years were evaluated pre and post season using: neuropsychological testing, transcranial magnetic stimulation (TMS), anatomical MRI, and diffusion tensor imaging (DTI). One athlete sustained a concussion and was subsequently removed from analysis.

Results

There was no significant difference when comparing pre- and post-season measures for: neuropsychological testing; intercortical ($p = 0.812$) or intracortical ($p = 0.888$) inhibition, measured by duration of silent periods during TMS; motor evoked potential onset ($p = 0.227$) or duration ($p = 0.977$); and interhemispheric conduction times ($p = 0.092$). In addition, no significant difference was found between pre and post assessments of fractional anisotropy, for white matter tracts of interest: posterior limb of internal capsule; cortical spinal tracts; and genu, body, and splenium of the corpus callosum.

Conclusion

Following a season of soccer, there was no difference in any neurologic parameters that would elicit concern for the continuation of the sport at this level. We demonstrate that the inter- and intra-cortical inhibitory parameters derived from TMS are stable; therefore, TMS and DTI can be used as reliable measures for further investigation of patients sustaining mTBI.

Brain-derived neurotrophic factor: Biopsychosocial correlates and exercise response in mild traumatic brain injury

Aliyah Snyder, MD; Russell Bauer; David Fitzgerald, MD; James Clugston; Floyd Thompson; Christopher Giza, MD, FAAN; Talin Babikian; Joshua Yarrow

Recovery from mild traumatic brain injury (mTBI) is a dynamic, complex process, and pre-clinical research highlights brain-derived neurotrophic factor (BDNF) as an important mediator in functional and pathophysiologic outcomes. Although BDNF appears to also be a significant factor in recovery in humans, its role is less understood. Our purpose was (1) to examine the association of serum and platelet-poor plasma concentrations of BDNF to relevant biopsychosocial outcomes of mTBI recovery (i.e., neurocognitive performance [attention, processing speed, memory, executive functioning], sleep, balance, mood, and self-reported symptoms) and (2) to assess BDNF response to a single-session of aerobic exercise (40 minutes of stationary cycling at 65%–75% maximum heart rate). There were 36 participants (ages 18–40; 19 male, 17 female) in 2 groups: (1) mTBI participants (n = 26) who were 14–25 days post-injury were randomized to either aerobic or non-aerobic exercise (low intensity stretching) and (2) demographically-matched, non-injured participants (n = 10) who participated in a single session of aerobic exercise. Results indicate that serum BDNF concentration has significant ($p = 0.05$), inverse relationships with both sleep dysfunction and state levels of anxiety. No significant association between exercise type and serum BDNF was found, but there was a small to medium effect size (= 0.08) for increased plasma BDNF after aerobic exercise in mTBI vs non-injured participants. Overall, peripheral BDNF concentrations are poorly correlated, which suggests they reflect different tissue sources. Serum BDNF was more sensitive to select biopsychosocial outcomes, particularly sleep quality and anxiety, regardless of injury status. Additionally, aerobic exercise may play a role in enhancing platelet-poor plasma BDNF response in the post-acute period after mTBI.

Biomarker signatures indicate Aldolase C, neurogranin, and synuclein beta are correlated with concussion history in mild TBI

Timothy Van Meter, PhD; Nazanin Mirshahi; W. Frank Peacock; Ramon Diaz-Arrastia, MD, FAAN; Ronel Veksler; Frederick Korley; Alon Friedman

Introduction

Concussion has been studied with increasing scrutiny in recent years, including evaluation of diagnostic technologies to detect structural damage to the brain. Previous studies in our laboratories using a number of TBI biomarkers have demonstrated the potential of blood biomarkers Neurogranin (NRGN), Oligodendrocyte myelin glycoprotein (OMG), and Synuclein beta (SNCB) as indicators of damage after concussion. This study was designed to evaluate the relationship of blood biomarkers with concussion history.

Methods

ELISA assays were developed to detect Aldolase C (ALDOC), Brain derived neurotrophic factor (BDNF), GFAP, Metallothionein-3 (MT3), NRGN, Neuron specific enolase (NSE), OMG, and SNCB. Serum concentrations were determined in replicate assays. Three cohorts were studied: mild TBI patients (HeadSMART; n = 139, Johns Hopkins University); healthy controls (n = 52, Baylor College of Medicine); and semi-professional football players (n = 31; Ben-Gurion University). Serum biomarker values were analyzed by Spearman's pairwise correlation to identify associations with prior concussion number, age, and years of play. Modeling in logistic regression was used to assess risk of PCS at 3 months.

Results

Prior concussion number was correlated with NRGN ($p = 0.58$), SNCB ($p = 0.42$), and ALDOC ($p = 0.64$) in players during the active season. Post-season, NRGN ($p = 0.53$) and ALDOC ($p = 0.37$) remain associated with concussion number. ALDOC and NRGN also correlated during the active season ($p = 0.68$), and ALDOC levels correlated with OMG (0.66), BDNF (−0.51) and NSE (−0.38). In HeadSMART mild-TBI, NRGN was correlated with ALDOC ($p = 0.44$), and SNCB and BDNF ($p = −0.33$), and OMG and NSE ($p = −0.33$) were weakly correlated. ALDOC, BDNF, GFAP, and OMG were associated with age, including decreasing ALDOC and NRGN with age. Classifier models confirmed the utility of these markers for predicting risk of ongoing symptoms (PCS) after mTBI.

Conclusion

Blood levels of NRGN and SNCB are consistently associated with concussion and have been shown to be useful for mTBI diagnosis. These markers, and ALDOC, are promising biomarkers for further development in sports-related concussion.

Quantitative analysis of neurometabolites in adolescents with persistent symptoms following concussion using magnetic resonance spectroscopy

Ryan Moonnoh Lee; Lezlie Espana; Robert Prost; Andrew Nencka; Kevin Koch; Timothy Bradley Meier, PhD

There is great interest in developing physiologic markers of persistent concussion symptoms (PCS) that can occur following mild traumatic brain injury (mTBI). Magnetic resonance spectroscopy (MRS) can non-invasively measure changes in brain metabolism and is directly translatable to clinical application. Previous studies have shown that mTBI is associated with decreases in N-acetylaspartate (NAA), though most prior work has focused on adults. In this pilot project, we hypothesized that adolescents with PCS would have decreased NAA in frontal white matter (FWM) and the anterior cingulate cortex (ACC) relative to adolescents without PCS. Twenty-two patients (14–18 years old) with persistent symptoms following sport or recreation-related concussion (PCS+) were recruited from a concussion clinic and assessed at least 4-week post-injury. Twenty-one adolescents with varying concussion history but without PCS served as controls (PCS–). Exclusion criteria included current or prior moderate/severe TBI, neurodevelopmental disorder, or psychiatric disorder unrelated to current injury. Participants completed a clinical assessment battery that included self-reported concussion and psychiatric symptoms and neurocognitive testing. MRS was performed in the ACC and right FWM using a PRESS sequence on a GE 3T scanner. Spectra were analyzed using LCModel to calculate metabolite levels. Independent samples t-tests were used to compare groups, with *apriori* analyses focused on NAA, NAA plus N-acetylaspartylglutamic acid (total NAA), and combined glutamate and glutamine (Glx). PCS+ showed significant elevations in concussion and psychiatric symptoms as well as decreased neurocognitive performance compared to controls ($p = 0.05$). In addition, PCS+ had a significant decrease in total NAA ($p = 0.012$) and a non-significant decrease in NAA ($p = 0.057$) in the FWM when compared to PCS–. No differences between groups were seen in the ACC ($p = 0.1$). Our results suggest a relationship between PCS in adolescents and decreased total NAA in frontal white matter. Additional analyses investigating the relationship between neuro metabolites and clinical measures are underway.

Disclosures: Dr. Lee has nothing to disclose. Dr. Espana has nothing to disclose. Dr. Prost has nothing to disclose. Dr. Nencka has nothing to disclose. Dr. Koch has nothing to disclose. Dr. Meier has nothing to disclose.

Neuroimaging of concussion patients in an outpatient clinic

Jennifer McVige, MD; Said Shukri; Vincent Bargnes; Michael Lillis

Objective

To evaluate the use of neuroimaging safety, diagnoses, and potential treatment of patients with concussion.

Methods

This retrospective study took advantage of a concussion database to analyze neuroimaging in concussion patients of all ages. Details of neuroimaging orders were tracked and categorized as hospital emergency rooms, primary care physicians, neurologists at DENT, or by other specialists. Neuroimaging consisted of MRI and/or CT scans, which were classified as normal or abnormal. Abnormal MRI scans consisted of white matter changes, brain hemorrhage, chiari malformation, cyst arachnoid, hydrocephalus, incidental unrelated finding, or a developmental venous anomaly. Abnormal was further defined as abnormal due to head injury, unrelated to the concussion but unlikely to prolong recovery time, or unrelated to the concussion but may prolong recovery time.

Results

Among the 835 diagnosed with concussion, 715 (86%) patients ages 1–78 had neuroimaging completed (615 MRI and 422 CT). Among these patients 401 (95%) had a CT order prior to coming to Dent, 319 (80%) from emergency rooms, 64 (16%) from primary care physicians, and 18 (4%) from other physician specialists. The rate of ordering an MRI was 46% greater than the rate of ordering a CT scans, while the rate of discovering an abnormality within MRI scans was 3 times greater than CTs (24.3% vs 7.8%).

Conclusions

There exists a remarkable discrepancy between the rate of ordering neuroimaging in concussion patients (46% more MRI vs CT orders) and the rate at which neuroimaging in these patients discovered brain abnormalities (×2.11 more in MRI vs CT reads). We acknowledge that improvement is required in the length of time in the MRI scanner and cost of MRI technology. However, additional consideration is required in abnormality detection effectiveness, cost efficiency, and radiation safety in balancing the use of MRI and CT technology.

Disclosures: Dr. McVige has received personal compensation for consulting, serving on a scientific advisory board, speaking, or other activities with Amgen, Avinir, Teva, and Supernus. Dr. Shukri has nothing to disclose. Dr. Bargnes has nothing to disclose. Dr. Lillis has nothing to disclose.

Changes in functional connectivity are associated with one season of head-to-ball impact exposure in male collegiate soccer athletes

Derek C. Monroe, PhD; David Keator; Robert Blumenfeld; James Hicks; Steven L. Small, MD, PhD, FAAN

Objectives

Return-to-play protocols could be improved by a better understanding of the physiologic effects of mild traumatic brain injury (mTBI). Autonomic dysregulation is thought to underlie many of the multi-dimensional symptoms following mTBI and may derive from altered connectivity in the brain central autonomic network (CAN). Understanding the relationship between injury and CAN connectivity could lead to a useful biomarker for mTBI. Toward this end, the present study aimed to establish a formal relationship between non-symptomatic head-to-ball impacts ("headers") and CAN connectivity in collegiate soccer athletes.

Methods

Eleven male NCAA Division I soccer players were monitored by athletic training staff throughout 1 season for the number of headers. Ten male NCAA Division I athletes (3 cross-country and 7 golfers) served as controls. All participants underwent resting-state fMRI pre- and post-season. Twenty ROIs were selected based on regions previously implicated in control and modulation of autonomic function. Graph theoretical analyses were used to probe changes in network architecture and connectivity. Specific contrasts focused on pre- and post-season changes that were explained by individual differences in exposure to headers ($p < 0.05$ uncorrected).

Results

Within the 20 node network, increases in headers were associated with reduced degree centrality of the left and right insular cortex and right putamen ($p < 0.02$), increased degree and betweenness centrality in the left anterior and right posterior Para hippocampal gyri ($p < 0.03$), and increased betweenness centrality in the anterior cingulate cortex ($p = 0.006$). Headers were also associated with reduced functional connectivity within the sub-network including the anterior cingulate cortex ($p = 0.0073$), right hippocampus, left putamen, and left insular cortex ($p < 0.04$).

Conclusion

Highly skilled soccer players who sustained the greatest number of head impacts also experienced the greatest altered connectivity among regions associated with autonomic function. Future work to establish autonomic function as an injury biomarker should consider the importance of cumulative impact magnitudes.

Disclosures: Dr. Monroe has nothing to disclose. Dr. Keator has nothing to disclose. Dr. Blumenfeld has nothing to disclose. Dr. Hicks has nothing to

Association of acute depressive symptoms and functional connectivity in emotional processing regions following sport-related concussion

Lezlie Espana; William McCuddy; Lindsay Nelson; Rasmus Birn; Andrew Mayer, PhD; Timothy Bradley Meier, PhD

Few studies have examined the physiologic correlates of depressive symptoms following sport-related concussion (SRC), despite the prevalence of these symptoms following brain injury. We hypothesized that concussed athletes would have disrupted resting-state functional connectivity in emotional processing regions compared to controls, and that this disruption would be associated with greater post-concussion symptoms of depression. Forty-three concussed athletes at approximately 1 day (N = 34), 1 week (N = 34), and 1 month (N = 30) post-concussion were evaluated along with 51 healthy athletes assessed at a single visit. Resting-state fMRI was collected on a 3T GE scanner (TR = 2s); depressive symptoms were assessed using the Hamilton Rating Scale for Depression (HAM-D). Emotional processing regions of interest (ROI) were defined using an automated meta-analysis of brain regions associated with the term "emotion". Fisher-Z transformed correlations were calculated between each ROI. A multivariate approach assessed connectivity by analyzing ROI as simultaneous response variables. Concussed athletes had significantly higher depressive symptoms relative to controls at all time points but showed partial recovery by 1-month post-concussion relative to earlier visits (p's< 0.05). Functional connectivity did not differ between controls and concussed athletes at 1 day or one-week post-concussion. However, concussed athletes had significantly different connectivity in regions associated with emotional processing at 1 month relative to 1 day post-concussion (p = 0.002), and relative to controls (p = 0.003). Follow-up analyses showed that increased connectivity between attention and default mode networks at 1-month post-concussion was common across both analyses. In addition, functional connectivity of emotional processing regions was significantly associated with depressive symptoms at 1 day (p = 0.003) and one-week post-concussion (p = 7×10^{-8}), with greater HAM-D scores correlating with decreased connectivity between attention and default mode networks. These results suggest that intrinsic connectivity between default mode and attention regions following SRC may be compensatory in nature.

Disclosures: Dr. Espana has nothing to disclose. Dr. McCuddy has nothing to disclose. Dr. Nelson has nothing to disclose. Dr. Birn has nothing to disclose. Dr. Mayer has nothing to disclose. Dr. Meier has nothing to disclose.

Advanced white matter mapping in the subconcussive brain

Bradley Caron; Nicholas Port; Franco Pestilli

The topic of behavioral and structural deficits caused by concussions is an increasingly important 1 in the related research fields. With an incidence rate of 2.9 competition concussions per 1,000 athlete exposures (NCAA 2013) in collegiate football, the concussion risk to athletes is significant. However, even subconcussive blows, or blows that do not lead to a concussion diagnosis, appear to create health risks for athletes. These impacts appear to lead to significant neural changes, the severity of which may depend on the number of hits (McAllister et al., 2014). An anatomically informed, personalized-medicine tractography approach was used to determine which major white matter tracts showed the greatest degree of difference in white matter tensor measures between 17 Division I upperclassmen football players, 15 Division I upperclassman cross-country runners, and 9 socioeconomically-matched non-athlete controls. We determined the underlying microstructural white matter biomarkers, using a classic diffusion-tensor model (Pierpaoli and Basser, 1999) as well as Neurite Orientation Dispersion and Density Imaging (NODDI; Zhang et al., 2012), that predict differences across different white matter tracts in the groups of athletes. Results show widespread differences in white matter tissue properties in multiple tracts and among the 3 athletes groups, including decreased FA, increased ICVF, and OD in the football players vs the 2 control groups. These differences occurred more often in longer fiber tracts compared to shorter fiber tracts, suggesting a differential effect of head impacts based on the geometric properties of these tracts. We developed a fully automated processing pipeline for this study, available as open source code as well as open service at brainlife.io. These results support the hypothesis that multiple subconcussive blows can result in white matter structural changes, with differential effects based on the length of the fiber tract being investigated, that are detectable with diffusion MRI and tractography.

Disclosures: Dr. Caron has nothing to disclose. Dr. Port has nothing to disclose. Dr. Pestilli has nothing to disclose.

Use of supervised exercise during recovery following sports-related concussion

Michael Popovich, MD; Andrea Almeida, MD; Jeremiah Freeman; James T. Eckner, MD; Bara Alsalaheen; Matthew T. Lorincz, MD, PhD; Andrew R. Sas, MD, PhD

Objective
To assess the safety of supervised exercise (SE) in acute sport related concussion (SRC), and explore its influence on recovery.

Background
Previous guidelines for the management of SRC have suggested complete physical and cognitive rest until asymptomatic, while he 2017 Berlin consensus statement now suggests return to light activity after 24–48 hours. The influence of early exercise on recovery following SRC remains unclear, and there is little evidence regarding its safety or efficacy.

Design/methods
Retrospective chart review of 124 patients with SRC who presented to a university sports neurology clinic within 30 days of injury between September 2016 and January 2017. Symptomatic patients who initiated SE within 16 days of injury were compared to those who did not undergo SE or initiated SE later than post-injury day 16 using Cox regression. The regression model controlled for multiple covariates including age, sex, history of previous concussions, injury severity, relevant co-morbidities, and other treatments received.

Results
No serious adverse events were observed in the early SE group. Furthermore, early SE was associated with earlier return to sport (hazard ratio = 2.35, p = 0.030), and the early SE group had fewer days from SRC until clearance for return to sport (mean 26.5 ± 11.2 days vs 35.1 ± 26.5 days, p = 0.020). There also was a non-significant trend toward fewer asymptomatic days in the early SE compared to non-early SE groups (mean 16.7 ± 7.1 days vs 22.4 ± 22.5 days, p = 0.054).

Conclusion
Early SE performed in the acute symptomatic stage of SRC was safe and was associated with earlier return to sport.

Disclosures: Dr. Popovich has nothing to disclose. Dr. Almeida has nothing to disclose. Dr. Freeman has nothing to disclose. Dr. Eckner has nothing to disclose. Dr. Alsalaheen has nothing to disclose. Dr. Lorincz has nothing to disclose. Dr. Sas has nothing to disclose.

Treating prolonged post-concussion symptoms in a pediatric patient with the simultaneous application of cognitive behavioral therapy and subthreshold exercise: A case study

Sonal Singh; Douglas R. Polster, PhD; Meeryo Choe, MD; Christopher Giza, MD, FAAN; Talin Babikian

Objective

Use a novel, simultaneously applied cognitive behavioral therapy (CBT) and subthreshold exercise treatment (STE) for a 14-year old patient with persistent post-concussion symptoms (PPCS) to facilitate a return to function in school/sport.

Background

Patient sustained a mild TBI while playing basketball on October 29, 2016. Neurologic exam on July 7, 2017 was negative, but the patient reported PPCS, with a graded symptom checklist (GSC) score of 26. Primary symptoms were headache and anxiety in relation to cognitive and/or physical exertion. The patient attributed anxiety to anticipating the onset of symptoms after exercise.

Design/methods

The 6-week combined CBT/STE intervention included psycho-education, cognitive restructuring, and relaxation training combined with the STE protocol. Supervised physical exertion exposure began with aerobic exercise on a stationary bike and progressed to sport-specific activity while the patient simultaneously engaged in CBT. Pre- and post-intervention data included physiologic measures (heart rate [HR] and power output [PO] on exercise bike), a subjective measure of exertion (Borg's Rating of Perceived Exertion [RPE]), and psychological self-report questionnaires.

Results

After 6 sessions, patient was able to engage in strenuous exercise with reduced symptom exacerbation as demonstrated by his ability to reach 175 bpm HR with 350 watts of PO with decreased reported symptoms, a significant improvement from the first session. The patient reported a decrease in anxiety and psychological distress as well as an increase in emotional and school functioning. Parent report indicated an increase in the patient's overall health, social, and emotional functioning.

Conclusions

Engaging in a six-week combined CBT/STE protocol resulted in improvements in ability to tolerate physical exertion, decreases in psychological distress, and a return to function. This case study demonstrated the feasibility & positive impact of simultaneous, dual treatment model for PPCS in adolescents. It also highlighted the need to address the psychological distress that occurs in patients with PPCS.

Time-of-day influence on the stability Evaluation Test in college-age women

Brandon Doan; Jeff Pasley; Tiffany Rodriguez; Katherine Valencia; Tim Tolbert

Postural control is impaired following a concussion and is 1 diagnostic method used by medical professionals for return-to-play decisions in potentially concussed athletes. Circadian rhythm (time-of-day) affects human function, including postural control. This research investigated time-of-day influence on 1 postural control diagnostic protocol, the Stability Evaluation Test (SET) on a Neurocom Balance Master. The Georgia Gwinnett College Institutional Review Board approved this research protocol. The research participants were 9 healthy women with an average age of 20.4 years, height of 165.8 cm, and weight of 65.3 kg. The participants completed the SET in the morning (between 7:00 AM and 10:00 AM) for 1 treatment and in the evening (between 3:00 PM and 7:00 PM) for the other treatment. A SET familiarization session was completed, and treatment order was randomized and balanced to attempt to account for order effects. Average postural sway velocity for each of the 6 SET conditions were compared between times of day. There was less postural sway during the morning testing for all conditions, reaching statistical significance ($p < 0.05$) for 2 of the more challenging balance conditions (Foam Double Leg and Foam Tandem) as well as for the overall SET composite score. While greater sample size, age and gender range are needed, these results may begin to inform practitioners as to the importance of controlling time-of-day between baseline and post-injury testing which may enable more accurate and reliable return-to-play decisions.

The effects of altitude on concussion incidence in the 2013–2017 National Hockey League seasons

Ryan Adams; Halley Kaye-Kauderer; Syed Haider; Akbar Maniya; Stanislaw Sobotka; Tanvir Choudhri

Introduction

Altitude cannot be adjusted yet can still impact quality of play and concussion incidence. The current body of published evidence evaluating environmental effects on concussion is divided. We aim to systematically compare the prevalence of concussions that occur utilizing 1,000 feet as a marker for high altitude. Our research also takes a novel approach utilizing average games missed as a proxy for concussion severity.

Methods

Data on concussion incidence for the 2013–2017 National Hockey League seasons was collected utilizing FOX Sports, Hockey Reference and elevation map. We adopted 1,000 feet (304.8 meters) as high-low altitude cutoff. We also evaluated our data utilizing a previously published high-low altitude cutoff of 644 feet. One caveat to our data collection was the striking lack of publicly available data pertaining to the concussions sustained by each NHL team. Data was analyzed utilizing SAS programing.

Results

We documented 133 concussions through the 2013–2017 NHL seasons. We noted an increase in concussion reporting during the most recent 2016–2017 season compared to previous ones. Effect of altitude variance on concussion rate was evaluated utilizing 644 and 1000 ft as the altitude split. This produced 4 distinct categories: (1) low-low, (2) low-high, (3) high-low, and (4) high-high. We noted a significant difference in concussion rate when teams based at altitude above 1,000 ft played at low altitude. Average games missed demonstrated that teams above 1,000 feet experienced less games missed compared to low altitude teams.

Conclusions

Though underreported in the total number of concussions, our data suggests that high altitude teams experience a reduction in mean concussion rate when playing at lower altitudes. Our data also indicated a reduction in average games missed post-concussion for higher altitude teams. We hope our findings contribute to a larger discussion about concussion incidence and can be applied to additional sports leagues.

to disclose. Dr. Sobotka has nothing to disclose. Dr. Choudhri has nothing to disclose.

Relationship between fractional anisotropy and neuropsychological evaluation in sports-related concussion

Haruo Nakayama; Yu Hiramoto; Yuriko Numata; Satoshi Fujita; Nozomi Hirai; Norihiko Saito; Morito Hayahsi; Kazuya Aoki; Satoshi Iwabuchi

Objective
To evaluate the relationship between functional anisotropy (FA) and neuropsychological evaluation in concussion.

Methods
Diffusion tensor MRI included FA of the Brain and neuropsychological evaluation were conducted on 10 patients with concussion who were diagnosed from April 2017 to March 2018. FA was extracted from 2 regions of interest in Corpus callosum (CC) and corticospinal tract (CT). Detailed neuropsychological testing with an emphasis on Working memory (WM) and Processing speed (PS) was also conducted. The FA value in that 2 regions were compared between the 2 groups of 5 patients (group F) who failed either in WM or PS and 5 cases (group NF) who did not admit it.

Results
Mean FA values in CC and CT in the Group F were 0.70 and 0.52. Mean FA values in CC and CT in the Group NF were 0.48 and 0.55.

Conclusions
Our result suggests that the FA value of CC did not explain the significant fluctuation of the neuropsychological function. However, FA value in CT were shown to explain the fluctuation of WM and PS.

Recovery time, risk factors, and volumetric analysis in acute mTBI

Teena Shetty, MD; Joseph Nguyen; Taylor Cogsil; Apostolos John Tsiouris; Sumit Niogi; Aashka Dalal; Kristin Halvorsen; Tianhao Zhang; Joseph C. Masdeu, MD, PhD, FAAN; Pratik Mukherjee; Luca Marinelli

Objective
This study investigated the influence of demographic factors, the course of recovery, and the utility of investigational MR sequences (specifically volumetry) in mild traumatic brain injury (mTBI) patients.

Background
Most literature suggests that the majority of mTBI patients achieve recovery within 1 month of injury, or sooner. This may be affected by younger age, female sex, concussion history, learning disability, psychiatric history, or migraines. The role of volumetric analysis in mTBI requires further investigation.

Methods
One hundred eleven patients (15–50 years old) enrolled in the study within 10 days of head injury. Patients completed a maximum of 4 encounters over 3 months, undergoing volumetric structural imaging at each visit. Patients were contacted to determine recovery date.

Results
Recovery date was obtained in 73 patients at HSS. The median days to recovery was 44 days (IQR: 23–88 days). 33% of this population was recovered in 30 days, 63% in 60 days, and >75% in 90 days. Of the subjects who were not recovered by 90 days, the right thalamus volume trended towards a negative correlation with SSS at that time point. Initial symptom severity score (SSS) was significantly correlated with increased days to recovery ($p = 0.382$, $p = 0.001$). Average days to recover was longer in patients with diagnosed depression, anxiety, or other psychiatric disorder (121 vs 70 days, $p = 0.037$). No significant differences in days to recovery were found between age groups, sex, learning disorder, previous concussions, or history of migraines.

Conclusion
Average time to recover from mTBI may be longer than previously reported. Acute SSS may be a useful indicator in determining recovery time. Of previously reported risk factors, personal psychiatric history may have the greatest effect on recovery time. Despite being interesting, the volumetric correlations did not survive multiple comparison corrections and may not be the most sensitive variable for mTBI imaging.

Migraine phenotype prolongs recovery time in traumatic brain injury (TBI)

Cynthia Bennett-Brown; Sarah Ostrowski-Delahanty; Tracy Lynn Johnson, RN; M. Cristina Victorio; Susan K. Klein

We proposed that children and adolescents who had headache of migraine phenotype at initial neurologic assessment after mild TBI would take longer to clear for return to play than those who did not have those headache characteristics. Additionally, we predicted that those with migraine phenotype would be more likely to have comorbid mood or cognitive symptoms, which would also contribute to prolonged recovery. To test this, we assessed all new patients for the presence or absence of migraine phenotype with the Three-Item ID migraine screener (Lipton et al. 2003) at the first outpatient visit. Over the 5 months follow up interval (October 2017–February 2018), office visit data for 121 patients (ages 0–19 years) showed that 61% presented initially with a migraine phenotype. In that interval, 48% % (N = 58) were cleared for return to play. Those with migraine phenotype headache took longer to clear (99 vs 71 days respectively, $p = 0.004$). Neither age nor gender made a significant impact on length of recovery when only the presence or absence of migraine phenotype alone was considered. If patients had a migraine (vs non-migraine) phenotype headache and comorbid cognitive or behavioral symptoms (38% in our sample), their time to recovery was prolonged (109 vs 74 days respectively; $F(1, 56) = 7.215$, $p = 0.009$). These data suggest that early identification of migraine phenotype in assessment of post-traumatic headache can lead to aggressive treatment of headache, thus shortening the interval of disability after TBI. Cognitive and behavioral symptoms seem to have additional impact on recovery and should be addressed and supported in rehabilitation.

High sensitivity C-reactive protein: Potential biomarker of inflammation in acute mTBI

Teena Shetty, MD; Taylor Cogsil; Aashka Dalal; Kristin Halvorsen; Kelianne Cummings; Joseph Nguyen

Objective

This study investigated the utility of high-sensitivity C-Reactive Protein (hsCRP) as a blood biomarker for mild traumatic brain injury (mTBI).

Background

Validation of a blood biomarker panel will greatly improve mTBI diagnosis and prognosis. hsCRP has been validated as a sensitive biomarker for inflammation. Previous studies have established relationships between CRP levels and TBI, but the utilization of hsCRP levels in assessing mTBI requires further exploration.

Methods

Retrospective chart review collected hsCRP values in acute mTBI patients seen within 30 days of injury. Patients with any comorbid diagnosis known to cause elevation of inflammatory proteins were excluded. Continuous hsCRP levels were transformed into quartiles: <0.200 mg/L for Quartile 1 (Q1); 0.200–0.415 mg/L for Quartile 2 (Q2); 0.415–1.100 mg/L for Quartile 3 (Q3); and ≥1.100 mg/L for Quartile 4 (Q4). Multivariable binary logistic regression modeling identified potential factors for elevated hsCRP at first visit. Cox regression analysis identified potential factors for delayed time to recovery.

Results

Three hundred twelve injuries in 311 patients were reviewed (mean age 21 ± 12 years, 53% female). Mean hsCRP was elevated patients who presented within 2 days of injury and was found to significantly decrease between first visit and 4 weeks post-injury ($p = 0.016$). Initial hsCRP level was positively correlated with age (r = 0.163, $p = 0.004$) and negatively associated with previous concussion history ($p = 0.031$). When analyzed as quartiles, patients in Q4 were more likely to have endorsed headache ($p = 0.036$) or fatigue ($p = 0.030$). Age significantly increased between quartiles ($p = 0.013$). Multivariable binary logistic regression showed that increased age (OR: 3.48) and patients presenting with headache (OR: 3.48) or fatigue (OR: 2.16) were significantly associated with increased risk of having an hsCRP level in Q4. Females (HR: 0.32) and increased age (HR: 0.95) were associated delayed time to recovery.

Conclusions

hsCRP may be a viable addition to acute and longitudinal biomarker panels for diagnosis and prognosis of mTBI.

Case study: An evidence based approach to the use of dry needling for a concussion within the cervicogenic pathway

Kristina Green; Hollie Walusz; Stephanie Naylor

Concussion management and treatment continues to be a popular topic of current literature. As discussion of concussion pathways continues to be highlighted, specific intervention strategies are gaining popularity as best treatment options. For patients that fall into the cervicogenic pathway of concussion, DN is an intervention modality that is becoming more prevalent in its use. This presentation will describe the common presentation of patients that fall within this concussion pathway and highlight how DN reduces pain and disability within this subset of patients. We will discuss the current evidence and efficacy of DN as an intervention tool in our clinical practice, specifically for the cervicogenic pathway of concussion. We will outline and demonstrate proper application procedures for DN within the cervical, occipital and temporal regions with discussion of safety considerations. We will then correlate this intervention tool with the use of outcome measures within clinical practice and tie it back to patient reported concussive symptoms. Finally, we will discuss the impact on time to resolution of symptoms DN can have in our patients. Learning Objectives: (1) Discuss the theory of Concussion Clinical Pathways. (2) Understand a specific clinical presentation of a patient within the Cervicogenic Pathway. (3) Define Dry Needling (DN). (4) Understand the utilization and pathophysiology behind DN in clinical practice. (5) Understand the proper application of DN in the cervical, occipital and temporal regions. (6) Recognize the benefit DN has on this specific pathway. (7) Recognize patients that can benefit from this intervention through the use of a case presentation.

Cannabis, concussion, and chronic pain: An ongoing retrospective analysis at Dent Neurologic Institute in Buffalo, NY

Jennifer McVige, MD; Vincent Harry Bargnes, III; Said Shukri; Laszlo Mechtler, MD, FAAN, FASN

Objective

To examine medical cannabis (MC) as treatment for concussion-related chronic pain.

Design/methods

Individuals with concussion often experience chronic discomfort from headaches. MC treatment was approved for use in chronic pain by New York State in March 2017. DENT has treated 4,123 patients with MC, including 2,792 for chronic pain and 142 with concussion symptoms. Sixty-six charts were reviewed, with a total of 100 expected by presentation.

Preliminary results

(1) The Patient Global Impression of Improvement (PGI-I) scale revealed 80% of patients experienced significant improvement in activity level and symptoms. (2) Five common concussion symptoms (headache, mood, sleep, attention, and dizziness) were evaluated via modified-Likert scale (0 rated as "Much Worse" and 10 as "Much Better"). Moderate improvement (MI) was defined as 7–8 and significant improvement (SI) 9–10. Improvement was greatest in mood (63% MI, 20% SI), sleep (53% MI, 23% SI), and headache (60% MI, 14% SI). (3) Quality of Life after Brain Injury Score (QOLIBRI) scores were obtained on patients who had started MC (46) and those who had not yet (19). Comparison of the groups showed a significant improvement ($p = 0.0035$) in quality of life in individuals on MC. (4) The routes of administration that produced optimal benefit were 1:1 (THC:CBD) oral tincture at an average dose of 1.5 mL TID for prophylaxis and 20:1 vapor pen for acute pain. Together these products cost an average of $242 per month. (5) 15% of patients reported side effects, all minimal, with 63% related to administration route (poor taste, cough). No patients discontinued MC due to side effects.

Conclusions

These results support MC as an option for treatment of concussion-related chronic pain. While prospective studies are required, these

preliminary results lay the foundation for investigating MC as a valid treatment for concussion and chronic pain.

A systematic review of the emotional responses of student athletes post concussion

Gaurav Majmudar; Jill Johnson; Evan Anderson; Sherry Morgan

Background
The estimated incidence of sports related concussion has increased from 300,000 in 2007 to over 1.6 million in 2017, with a large percentage occurring in youth athletes. There are growing concerns about the cognitive and emotional wellbeing of young athletes during concussion recovery.

Objective
To review research evaluating how concussion relates to changes in emotion and mood in high school and college athletes.

Design/methods
Relevant articles from 1997 to 2017 were searched on PubMed using keywords and official MeSH terms such as: (1) concussion; or brain injuries, traumatic; or TBI and (2) high school; or college; and, (3) depression; or affect; or mood. English language articles were included for analysis if they measured concussed high school or college athletes using a validated instrument for assessing emotion and mood.

Results
Ten published studies met the inclusion criteria. Five studies measured changes in emotional response in athletes after concussion. The other studies compared emotional response in athletes after concussion to the emotional response in athletes after non-concussive sports injury, such as musculoskeletal, or orthopedic injury.

Conclusion
Despite heterogeneity in methods and limitations in the literature, our review suggests growing consensus that concussions result in altered emotions and mood. However, current research shows conflicting results on whether alterations in emotional response are different post-concussion than post non-concussive sports injury.

A comprehensive "Concussion Recovery Program" with emphasis on brain coaching and EEG-based neurofeedback therapy: A retrospective analysis

Majid Fotuhi, MD, PhD

Purpose
We have developed and implemented a "Concussion Recovery Program" (CRP) which combines promising treatment strategies from the medical literature into a comprehensive, multidisciplinary, and personalized program for patients with Post-Concussive Syndrome (PCS). The program's goal is to treat all of a patient's PCS-related symptoms under the care of a single physician. Patients receive brain coaching twice weekly in order to address their anxiety, insomnia, attention, headache, and fatigue issues. We also use EEG-based neurofeedback twice weekly to complement brain coaching sessions. Patients median time spent in the program was 16 weeks, during which they received a median number of 21 brain coaching sessions and 22 neurofeedback sessions.

Methods
To evaluate the effectiveness of CRP, we performed a retrospective, exploratory analysis using de-identified patient data from the Neurogrow Brain Fitness Center (Virginia, USA; approved by the New England IRB). We used a computerized cognitive testing tool, called CNS Vital Signs, to evaluate the cognitive performance of patients at the beginning and end of the program.

Results
Data from 46 patients reviewed showed significant improvements in several cognitive domains. Primary outcome measures were the 3 CNS Vital Signs domains known to be most sensitive to mild traumatic brain injury: Complex Attention, Cognitive Flexibility, and Executive Functioning. Paired t-tests were used to compare mean scores before and after treatment. For all 3 domains, patients experienced significant improvement after treatment ($p < 0.00001$), with medium or large effect sizes. For all 3 domains, over half of patients experienced score improvements greater than the Reliable Change Index.

Conclusions
Patients with PCS who completed our CRP experienced significant improvements in their symptoms. These results are promising and now a larger prospective study is warranted.

Use of event related potential markers in patients with traumatic brain injury

Tad Dean Seifert, MD; Marco Cecchi

Objective
To investigate whether event related potentials (ERP) could improve diagnosis and management of traumatic brain injury (TBI) patients in an outpatient setting.

Background
Though important progress has been made in our understanding of how traumatic brain injury (TBI) affects the brain, diagnosis remains suboptimal, especially in the mild stages of the disease. A real time physiologic measure of brain cortical synaptic function such as event related potentials (ERP) can measure the sensory and cognitive deficits that follow TBI even at the subclinical stages of the disease. Even though the potential of ERP as a diagnostic tool for TBI has been known for several years, the impracticality of running ERP tests in clinical environments on real patients has limited widespread clinical application in the past. Recently, advances in electronics and analysis algorithms have made it practical for ERP tests to be administered in outpatient settings on real patients, thus creating an opportunity to evaluate ERP as an index of functional pathophysiology for TBI in clinical environments.

Design/methods
Three patients with acute mild TBI were administered an auditory oddball ERP paradigm in conjunction with standard clinical evaluation.

Results
ERPs were an informative measure for understanding covert deficits in cognition. Several ERP components revealed selective dysfunction following sport concussion. ERP testing in this case series increased confidence in diagnosis and prognosis for this population of sport-related concussion, thus leading to better patient management. Through this data, we are now equipped with better insight on which TBI patients

would benefit most from the addition of ERP testing to the standard clinical workup.

Conclusions

Analysis of ERP data provides valuable information in patients with TBI, especially in mild cases where neuroimaging studies are non-revealing.

The association of reported cognitive symptoms and objective cognitive performance in patients with prolonged post-concussion symptoms

Douglas R. Polster, PhD; Aliyah Snyder, PhD; Alma Martinez; Collin Blout; Christopher Giza, MD, FAAN; Talin Babikian

Objective

Within a sample of patients with prolonged post-concussion symptoms, the current study evaluated the etiology of patients reported cognitive symptoms.

Background

Approximately 20% of individuals who sustain a concussion will go on to have prolonged post-concussion symptoms. There has been little research examining how patients' perceived symptoms relate to objective markers, especially in regard to perceived cognitive symptoms (e.g., difficulty concentrating). It is important to understand what contributes to patients' reported complaints in order inform prognosis as well as identify areas for intervention. We hypothesize that patients reported cognitive complaints are better accounted for by other concussion symptoms (e.g., somatic, affective, sleep) than by difficulties in their underlying cognitive abilities.

Methods

Thirty-seven patients between the ages of 12–23 were retrospectively included in the study based on the following: reported post-concussion symptoms, evaluated between 1 month and 1 year post-injury. Hierarchical linear regression analysis was used to test if objective cognitive performance, as measured by a verbal learning/memory task (RAVLT Total) and an attention/working memory task (WAIS-IV Digit Span Total), significantly predicted reported cognitive symptoms above and beyond somatic, sleep, and affective symptoms.

Results

Results of the regression analyses indicated somatic, sleep, and affective symptoms significantly explained 50.3% of the variance in reported cognitive symptoms. Objective cognitive performance did not significantly predict reported cognitive symptoms above and beyond the 3 other symptom factors (R2 Change = 0.04, F [2,31] = 1.45, $p = 0.25$). Additionally, objective cognitive performance was not a significant predictor of reported cognitive symptoms, explaining only 2.4% of the variance.

Conclusions

Results suggest cognitive difficulties are unlikely related to underlying neurocognitive pathology, but instead are related to functional challenges in the face of other symptoms (e.g., headache). Treatment of patients with cognitive complaints should focus on their entire symptom set, likely leading to a reduction in cognitive complaints.

Stable recovery during and after 6-week aerobic exercise with limbs blood flow restriction and body cooling in post-concussion syndrome

Yi-Ning Wu; Jessica Gravel; Matthew White; Josh Avery; Terrie Enis; Caroline Stark; Robert Cantu, MD

Recent research has shown that exercise can improve post-concussion symptoms. It might be because exercise-induced human growth hormone enhances the brain function and recovery. Exercise under blood flow restriction (BFR) and cooling triggers physiologic responses at a relatively low intensity that might be beneficial to individuals with PCS and requires further investigation. Therefore, our ongoing study is to examine the outcomes of aerobic exercise with (experimental) or without (control) BFR and cooling. Twenty-three participants with PCS less than 1 year were randomly assigned to the control or the experimental groups. Both groups rode the recumbent bike (NuStep) for 30 minutes at 60% of the predicted heart rate while only the experimental group exercised under BFR and cooling (Vasper system) twice a week for 6 weeks followed by 6 weeks of no intervention. In addition to the aerobic exercise, each participant received the standardized physical therapy as part of the 6-week intervention. A post-concussion Symptoms/Signs checklist was filled daily by the participant for 12 weeks. To examine the symptoms fluctuations, the variances of checklist scores for each participant during the intervention period and over the 6 weeks of no intervention were calculated. Mann-Whitney U test showed that variability of the overall symptom severity was significantly less in the experimental group ($p = 0.01$) during the intervention period, and the overall concussion load remained significantly stable in the experimental group ($p = 0.02$) after the intervention ended. These preliminary results have demonstrated that aerobic exercise with BFR and cooling enhances the recovery of PCS. Aerobic exercise alleviated the post-concussion symptoms of individuals with PCS less than 1 year. More stable recovery was found in the individuals who exercised at 60% of predicted maximum heart rate under BFR and body cooling as compared to the individuals without body cooling and BFR.

Heart rate variability as it pertains to sports related concussion and post-concussion syndrome

Thomas Bottiglieri; Randy Casals

Context

Sports related concussions (SRC), occur frequently in contact and collision sports and detection relies predominantly on subjective reports by athletes themselves. A non-invasive means of monitoring brain function and injury is desirable. Existing literature has established autonomic nervous system (ANS) dysfunction in the setting of brain injury. Heart rate variability (HRV) has been accepted as a means of measuring ANS function and correlation of ANS dysregulation after brain injury through HRV measurement can aid in the detection of concussions, monitoring of recovery, and may offer a target for intervention.

Methods

The studies included were found on the Ovid MEDLINE, PubMed, and Google Scholar databases through searches of the following keywords:

HRV, heart rate variability and concussion, post-concussion syndrome, and HRV biofeedback. We excluded studies that were not in English and did not meet the inclusion criteria of pertaining to SRC, sports performance, or ANS function.

Design
Clinical review.

Results
Current literature supports the notion that SRC causes dysregulation of the ANS, which can be detecting through changes in HRV. Monitoring HR and analyzing HRV can be used as a tool to detect SRC, monitor recovery, and set a target for treatment. Biofeedback techniques targeting HRV have been used to improve HRV and expedite recovery from SRC.

Conclusion
Existing literature has shown HRV is a tool for concussion detection and HRV biofeedback can aid in recovery. More rigorous study of the best ways to measure HRV in athletes, qualify and quantify changes in HRV specific to SRC, timing of change, timing of resolution of ANS dysfunction, and clinical significance of persistent HRV change after injury were all identified as targets for future research. Interventional studies evaluating the use of biofeedback as a means of improving HRV and reducing concussion symptoms severity and duration are warranted as well.

Disclosures: Dr. Bottiglieri has received personal compensation for activities with Global Medical Imaging as an education video creator. Dr. Bottiglieri has received personal compensation in an editorial capacity for Fidia Pharma. Dr. Casals has nothing to disclose.

fNCI-directed treatment of sports related post-concussion syndrome ion syndrome

Christiane Paney; Marci Johnson; Alina Fong; Mark Allen

Purpose
We propose that our individualized Enhanced Performance in Cognition (EPIC) Treatment can effectively address PCS in sports-related concussions by employing functional NeuroCognitive imaging (fNCI) in conjunction with post-concussion symptom scale measurements to inform and direct treatment modalities. fNCI is a specialized application of fMRI that utilizes a normative reference sample and biomarkers for concussion to provide sensitive and specific predictive diagnostic values. The fNCI addresses neurovascular coupling (NVC) dysregulation that commonly arises in PCS. These results inform individualized EPIC Treatment to restore normal NVC function with a treatment protocol that strategically integrates cardiovascular therapies with cognitive training.

Methods
Two hundred four sports concussion patients were assessed pre- and post-treatment using both objective (fNCI) and subjective Post-Concussion Symptom Scale (PCSS) measures, establishing pre-treatment benchmarks to measure therapeutic effectiveness. Patients underwent EPIC Treatment, which is a week-long, multiple treatments per day period consisting of cognitive, occupational, and neuromuscular therapy informed by fNCI and standardized PCSS findings.

Results
fNCI Severity Index Score (SIS) reported an average 80 percent reduction in objective measurements from the pre-treatment scan. Subjective measurements from the Post-Concussion Symptoms Scale (PCSS) reveal 59 percent reduction of symptoms as described by patient report. The SIS measurements are stable in follow-up scans 1-year post-treatment.

Conclusion
We provide evidence that fNCI can be used in assessment and treatment of chronic PCS resulting from SRC. Furthermore, the results provide evidence that our fNCI-guided treatment has positive outcomes in both objective and subjective measurements. This supports the hypothesis that our treatment effectively addresses PCS symptoms resulting from SRC. Follow-up fNCI scans indicate that improvements are stable following treatment.

Significance
SRC patients suffering from chronic PCS who were assessed by fNCI and underwent EPIC treatment report immediate, sustainable, and longitudinal reduction in symptoms resulting in significant improvements to quality of life and functionality.

Disclosures: Dr. Paney has received personal compensation for activities with Cognitive FX as an employee. Dr. Johnson has received personal compensation for activities with Cognitive FX as an employee. Dr. Fong has nothing to disclose. Dr. Allen has nothing to disclose.

Dual tasking to optimize performance for the tactical athlete
Selena Bobula; Jami Skarda-Craft; Alicia Souvignier

This session with cover aspects of the DoD's Intrepid Spirit (IS) model for caring for service members with symptoms of traumatic brain injury (TBI) and comorbidities and taking care further with interdisciplinary management of the high-level functioning tactical athlete. Traumatic brain injury and concussion are common injuries among service members and athletes. As more research is completed on concussion, consequences of this injury have become better understood, but much is still left unknown, to include proper treatment for high performance tactical athletes and service members. This lecture will discuss interdisciplinary treatment for high-level performance needs with emphasis on utilization of dual tasking. This session will describe the IS mission and programs available through the Warrior Recovery Center at Fort Carson then further expand upon specialized co-treatments between Speech-Language Pathology (SLP) and Physical Therapy (PT) to push high-level patients to a higher standard. These interventions include aggressive dual-task demands with balance, exertional, and endurance tasks combined with challenges of working memory, delayed recall, visual tracking, language fluency, visual reasoning, and executive functions in English and the service member's secondary language. A case report will be provided to offer example interventions as well as improvements throughout treatment for service members who participated in this advanced intervention.

Disclosures: Dr. Bobula has nothing to disclose. Dr. Skarda-Craft has nothing to disclose. Dr. Souvignier has nothing to disclose.

Determining aerobic capacity at symptomatic threshold in individuals with persistent concussion symptoms
Jacob James Michael Kay, MS; R. Davis Moore

Context
Research on exercise for concussion rehabilitation is gaining considerable attention. However, unless adequately prescribed, exercise can induce/exacerbate symptoms and impede neurologic recovery. Therefore, the primary purpose of this investigation was to determine the metabolic rate and aerobic capacity at symptomatic threshold in concussed individuals.

Methods
Thirty-seven concussed individuals (men = 14, women = 23; 22.97 years, ±5.13) completed a graded exercise test on a stationary bike using a modified Balke protocol. Symptoms (SCAT-4) and physical exertion (Borg Scale) were periodically monitored throughout testing, which

ceased at the induction/exacerbation of symptoms. Aerobic capacity was assessed using an estimated VO2max calculation (ACSM, 2015). Descriptive and correlation statistics were computed with an apriori alpha level of 0.05.

Results

We observed that symptoms were induced/exacerbated at a mean power output of 95.24W (±34.30), which corresponded to a mean estimated VO2max of 21.29 (±5.84) mL/kg/min and a mean metabolic equivalent of 6.08 (±1.67) METs. No significant differences between men and women were observed. Interestingly, neither total number of symptoms, total symptom score (SCAT-4), nor self-report pre-test cardiorespiratory fitness level (Huet questionnaire) correlated with aerobic capacity at symptomatic threshold ($p = 0.05$).

Conclusions

Our results help to establish the symptomatic threshold in concussed individuals during exercise. Importantly, we did not find a significant correlation between cardiorespiratory fitness and symptom threshold, suggesting a fundamental change in underlying physiology induced by concussion. These findings can be used to design safer graded exercise protocols that aim to enhance rehabilitative efficacy. Further, MET conversions may provide a useful tool in guiding rehabilitation of concussed individuals in every day activities. Our data indicate that concussed individuals would benefit from initiating physical activity at an intensity level below the metabolic and aerobic capacity thresholds described herein.

Disclosures: Dr. Kay has nothing to disclose. Dr. Moore has nothing to disclose.

Why do pediatric athletes continue to play after concussion?

Bert B. Vargas, MD, FAAN; Aaron Zynda; Meagan Sabatino; Jane Chung; Munro Cullum, PhD; Shane Miller

Purpose

As sport-related concussion incidence has increased in the pediatric population, the risks of continuing to play while injured have become apparent. These risks include subsequent injury, prolonged recovery, and Second Impact Syndrome. The purpose of this study was to determine why pediatric athletes continue to play following a concussion.

Methods

Prospectively collected data of subjects enrolled in the North Texas Concussion Network Registry (ConTex) between December 2015 and April 2018 was reviewed. Subjects were included in this analysis if they were diagnosed with a sport-related concussion, less than 19 years old at time of injury, reported they continued to play, and provided a reason for continuing play.

Results

Two hundred fifty-eight subjects met inclusion criteria. Mean age was 13.9 years (range: 7–18 years) and 130 (50.4%) subjects were female. One hundred forty-two (55%) subjects reported they continued to play following their concussion. Of those subjects who continued to play, 45 (31.7%) reported they "felt okay at the time" 41 (28.9%) reported they wanted to "play through the injury or tough it out" 36 (25.4%) reported they "did not realize it was a concussion" 17 (11.9%) reported they "felt pressured to play from their coach or teammates" and 3 (2.1%) reported they "were allowed to continue to play by an athletic trainer." No significant differences were noted in age, gender, or sport of the pediatric athletes amongst the reasons for continuing to play.

Conclusions

More than half of pediatric athletes continued to play following their concussion. Pediatric athletes most frequently continued to play because

they were not experiencing symptoms at the time of the injury, wanted to play through it, and did not think their injury was a concussion. Future educational programs should take these reasons into consideration to prevent pediatric athletes from continuing to play following a concussion.

Disclosures: Dr. Vargas has received personal compensation from Amgen, Alder, Allergan, Avanir, Pernix, Teva, Lilly, and Upsher-Smith for consulting, serving on a scientific advisory board, speaking, or other activities. Dr. Zynda has nothing to disclose. Dr. Sabatino has nothing to disclose. Dr. Chung has nothing to disclose. Dr. Cullum has nothing to disclose. Dr. Miller has nothing to disclose.

Secular trends in emergency department encounters for concussion at US children's hospitals by age group (2008–2017)

Amy Linabery; Kara Seaton; Alicia Zagel; Alicen Spaulding; Gretchen Cutler; Robb Doss; Anupam Kharbanda

Background

Increased concussion rates in US youth have been documented since 2000. Concomitant rises in healthcare utilization for concussion are likely attributable to public health, media, and legislative initiatives aimed at increasing public awareness of the importance of seeking medical attention after injury. Utilization trends in young children have not been well-documented, however.

Objective

To characterize recent secular trends in pediatric emergency department (ED) encounters for concussion by 4-year age group.

Methods

Using Children's Hospital Association's Pediatric Health Information System data, we examined a retrospective cohort of patients aged 2–17 years with an ED encounter for concussion at 22 US pediatric hospitals with continuous data between 2008 and 2017. Average annual change in rates of ED visits for concussion and sports-/recreation-related concussion, imaging, and admissions were estimated via weighted least-squares regression.

Results

ED encounters with a primary indication of concussion comprised 0.8% (n = 86,393) of all ED encounters in 2008–2017. Over time, ED concussion visits in 6–17-year-olds increased by 0.5–1.1 per 1,000 ED encounters per year (all P_{trend}< 0.0001), while rates among 2-5-year-olds remained stable (P_{trend} = 0.72). Rates for sports-/recreation-related concussions increased significantly across all age groups ($<0.0001 ≤ P_{trend} ≤ 0.01$). Absolute number undergoing any imaging increased in all age groups; however, due to increased ED concussion encounters, the rate of imaging decreased overall (−29.7/1,000 ED concussion encounters/year; $P_{trend} < 0.0001$) and across all age groups; the imaging rate decreased less for 2-5-year-olds (−19.6/1,000 encounters/year; $P_{trend} < 0.0001$). Likewise, admission rates declined significantly over time overall (−10.1/1,000 encounters/y; $P_{trend} = 0.0006$) and for all age groups.

Conclusions

ED concussion encounter rates in US youth aged 6–17 years continue to increase at pediatric hospitals, suggesting awareness efforts have been effective. Conversely, imaging and admission rates have decreased, indicating efforts to curtail unnecessary irradiation and intervention have also been successful. Trends in 2-5-year-olds were somewhat different from older youth and should be explored further.

Disclosures: Dr. Linabery has nothing to disclose. Dr. Seaton has nothing to disclose. Dr. Zagel has nothing to disclose. Dr. Spaulding has nothing to disclose. Dr. Cutler has nothing to disclose. Dr. Doss has nothing to disclose. Dr. Kharbanda has nothing to disclose.

Gender differences in outcome following pediatric concussion

Jacob James Michael Kay, MS; Chandler Melton; Jeff Holloway; Davis Moore

Context

Concussive injuries result in various somatic, cognitive, and mental health alterations which can negatively influence academic and vocational performance. Research demonstrates that gender may moderate concussion recovery, with females appearing to experience more severe and more protracted symptoms than males. However, we are just beginning to understand gender-based differences in concussion recovery, particularly during development. Accordingly, the purpose of our investigation was to advance the extant knowledge by examining the role of gender in concussion recovery in a pediatric population.

Methods

Data were collected from a local pediatric sports medicine clinic. Participants (8–18 years) who sustained concussions during the 2017–2018 school years were examined. Outcome measures of somatic (Rivermead Post-concussion Symptom Questionnaire), cognitive (CogState Brain Injury Battery), and mental health (Beck Depression Inventory-Youth) symptoms were analyzed. Key demographic variables (e.g., age, SES, medical history) and injury characteristics (e.g., time since injury, number of prior concussion) were controlled for in the statistical analyses.

Results

Preliminary findings indicated a significant gender difference in self-reported somatic symptoms ($p < 0.05$), with females (M = 5.3, SD = 3.8) reporting greater symptom scores on the Rivermead Post-concussion Symptom Questionnaire than males (M = 2.8, SD = 2.5). In contrast, no significant differences were observed for any metric of cognition or mental health ($ps \geq 0.15$).

Conclusions

Our findings corroborate evidence that concussed females report greater clinical symptoms than do concussed males. Importantly, no gender differences were observed in terms of cognition or mental health. Thus, differences in concussion symptom scales may not be useful proxies of cognitive or mental health. Future researchers and clinicians should go beyond concussion symptom scales to gain a more accurate understanding of gender differences, if any, following concussion.

Disclosures: Dr. Kay has nothing to disclose. Dr. Melton has nothing to disclose. Dr. Holloway has nothing to disclose. Dr. Moore has nothing to disclose.

Executive functions in adolescent hockey players competing with different rules for body checking

Jean-Christophe Lortie; Veronik Sicard; Robert Davis Moore; Dave Ellemberg

A history of multiple concussions may lead to later-life neurodegeneration and persistent cognitive impairment. Repeated subconcussive impacts over a career could play a role in this process, however evidence remains limited. Although imaging studies reveal cortical thinning and white matter changes, no impairments are detected in neuropsychological studies. Thus, we sought to explore the effect of body checking experience, which can be considered as repeated subconcussive impacts, on executive functions in young hockey players. Sixty-six young hockey players, aged between 12 and 17 years, went through a preseason baseline cognitive testing. In this age range, players are separated into 3 groups according to the body checking rule each division is playing (i.e., full body checking, progressive body checking, and no body checking). Executive functions were assessed using a task-switching paradigm. Primary outcome measures were accuracy and reaction time. An ANCOVA with age as covariate was conducted to compare groups according to the body checking rule they have experienced. Analysis revealed no significant group difference in task performance ($p = 0.91$), suggesting that executive functions are not influenced by body checking experience. Age strongly correlated with accuracy ($p = 0.01$; $r^2 = 0.37$), suggesting that younger athletes performed poorly on the task relative to their older teammates. These preliminary results support that body checking experience did not appear to affect executive functions in adolescent hockey players. However, age seemed to be a predictor of accuracy agreeing with literature that executive functions continue to develop during adolescence. A post-season testing will be conducted to investigate the effect of body checking on executive functions over an entire season.

Disclosures: Dr. Lortie has nothing to disclose. Dr. Sicard has nothing to disclose. Dr. Moore has nothing to disclose. Dr. Ellemberg has nothing to disclose.

Concussion in youth sports: A survey study assessing knowledge, attitude, & experience

Kacie Kidd; Trevor M. Jones; Pamela Murray; Alex Ritter; Andrew Cole Gurtis

Purpose

Research on concussive injuries among athletes has increased substantially but is limited due to the lack of studies involving adolescent athletes, who experience the majority of sports-related concussions, and differences by sex and sport. The purpose of this study is to better understand how adolescents comprehend and experience concussions.

Methods

A survey assessing knowledge, attitude, and experience regarding concussion was administered to athletes ages 10–17 in the spring of 2016 and 2017. Data collection occurred during an annual sports physical event and was administered on laptop computers. Analysis included descriptive statistics as well as the χ^2 testing of scores reflecting knowledge and attitude among participants by age, gender, and sport.

Results

In total, 208 athletes (50.96% male, average age 13.6 years, SD 1.84) completed the survey and (33, 16%) endorsed a history of concussion. They participated in 21 different sports and the majority (64%) received formal concussion education. While 98% understood that they were not allowed to return to play on the same day they were concussed, 50% indicated that they would continue to play with a headache sustained from a sport injury. When comparting the sports athletes played, attitude score trends were more positive among low-impact sport athletes when compared to high-impact sport athletes ($p = 0.0291$).

Conclusions

While a high prevalence of concussions and unhealthy attitudes toward reporting are found at the highest levels of professional and collegiate athletics, this study provides evidence that youth athletes are also vulnerable. This study and similar works on older populations suggest that a paradigm shift is likely necessary to change the culture of athletics beginning at the youngest levels with an emphasis on the responsibility to protect one's brain over the need to get back in the game.

Disclosures: Dr. Kidd has nothing to disclose. Dr. Jones has received personal compensation from HealthWorks Rehab & Fitness as an employee. Dr. Murray has nothing to disclose. Dr. Ritter has nothing to disclose. Dr. Gurtis has nothing to disclose.

The gaps of concussion policy in soccer: A visual review

Nikesh Bajaj, DO

Concussion evaluation and treatment has been widely less widely publicized in soccer vs American football. However, a recent assessment found that in the previous FIFA World Cup in 2014, 63% of events when

players involved in head collisions were not assessed by sideline healthcare personnel within the 64 matches of the tournament. The upcoming 2018 FIFA World Cup should be approached with a more critical eye in order to improve the rate of concussion assessment in head collisions. US Soccer National Team's Concussion policy "players who are suspected of having sustained a concussion shall be removed from play immediately and evaluated by team medical staff." Not all head collisions are required to be examined and a physician is not required to perform the sideline evaluation. Since the start of the 2018 Major League Soccer season, at least 2 incidents of concussion diagnosis were instances which an initial evaluation allowed the player to return to play when a concussion diagnosis was made later. A detailed examination of professional soccer both on the American and World stage exposes gaps in concussion policy that must be addressed to improve the approach to athlete brain health.

Disclosures: Dr. Bajaj has nothing to disclose.

Streamlining clinical research: The National Institute of Neurological Disorders and Stroke (NINDS), National Institutes of Health (NIH) and Department of Defense (DoD) sport-related concussion common data element (CDE) recommendations

Kristen R. Joseph, MA; Carolina Mendoza-Puccini; Joy R. Esterlitz; Katelyn Elizabeth Gay; Muniza Sheikh; Patrick Bellgowan

Objective
The purpose of the NINDS CDE project is to educate new clinical investigators, increase efficiency and effectiveness of clinical research studies and treatment, increase data quality, facilitate data sharing, significantly reduce study start-up time, and more effectively aggregate information into significant metadata results. In 2016, as part of the NINDS CDE project to develop data standards for all clinical neuroscience research, NINDS, NIH and the DoD initiated the development of Sport-Related Concussion (SRC) CDEs.

Background
TBI CDE recommendations were published on the NINDS CDE website in 2010, but lacked a thorough inclusion of SRC. In August 2016, a new SRC-specific working group (WG) began developing and identifying CDEs, template case report forms (CRFs), and guidelines to assist investigators conducting SRC-specific clinical research studies.

Design/methods
The CDE WG, which consisted of 34 worldwide SRC research experts, met regularly via teleconference over several months. The WG was divided into 3 subgroups to examine SRC during defined periods relative to time of injury: Acute (72 hours post-concussion), Sub-Acute (3 days-3 months post-concussion) and Persistent/Chronic (3 months and greater post-concussion).

Results
Version 1.0 of the SRC CDEs were available on the NINDS CDE website in June 2017. These include Core and Supplemental, Highly Recommended CDEs or instruments for cognitive measures and symptom checklists, as well as, other outcomes and endpoints, and sample CRFs for domains typically included in clinical research studies (e.g., vestibular, oculomotor, balance, anxiety, depression).

Conclusion
The NINDS CDEs are reviewed and updated regularly as research advancements or changes to specific recommendations are deemed appropriate. Because the CDEs are an evolving resource, continued feedback is important for improved use and utility. The use of SRC CDE recommendations is highly encouraged for SRC related researchers as they serve as a valuable starting point and facilitate streamlining and sharing data.

Disclosures: Dr. Joseph has nothing to disclose. Dr. Mendoza-Puccini has nothing to disclose. Dr. Esterlitz has nothing to disclose. Dr. Gay has nothing to disclose. Dr. Sheikh has nothing to disclose. Dr. Bellgowan has nothing to disclose.

Resting metabolic rate following sport concussion: A preliminary analysis

Samuel R. Walton, MEd; Candace Bernitt; Brooke Daniell; Steven Malin; Jacob Resch

Objective
Alterations in energy expenditure have been observed following moderate and severe traumatic brain injury (TBI) in animals and humans. However, few data exist characterizing how mild TBI, specifically concussion, affects whole-body energy expenditure. The purpose of this study was to examine resting metabolic rate (RMR) following sport concussion in university and high school student-athletes.

Methods
Concussed participants were recruited from a university and local high schools. Concussion diagnosis was made by an athletic trainer or physician. Participants could have no other concurrent injury (e.g., fracture). RMR was determined by indirect calorimetry (VMax Metabolic Cart) with a ventilated hood < 72 hours following a diagnosed concussion (T1), 7 days after T1 (T2), and 7 days after T2 (T3). Predicted RMR (pRMR) was also calculated using 3 validated equations: Harris-Benedict (HB), Mifflin-St. Jeor (MSJ) and Schofield (SCH). These equations were used to examine the magnitude of change in RMR following concussion. Measured and predicted values were compared at each time point using percentages ([RMR/pRMR] × 100). Changes over time in measured RMR were assessed using a repeated measures ANOVA.

Results
Twelve concussed participants (aged 17.7 + 2.15 years, BMI 21.8 + 2.94) completed T1 at 1.8 + 0.84 days post-injury. There were 3 participants of each sex from each academic setting (university and high school). Measured RMR percent of pRMR was below 100% at each time point post-concussion (T1: HB = 53% + 7.6%, MSJ = 55% + 8.6%, SCH = 53% + 9.1%; T2: HB = 54% + 6.6%, MSJ = 56% + 6.7%, SCH = 53% + 8.1%; and T3: HB = 57% + 8.5%, MSJ = 59% + 9.6%, SCH = 57% + 9.0%). Additionally, measured RMR did not change over time (T1 = 909 + 226.0 kcal, T2 = 905 + 154.5 kcal, T3 = 975 + 266.7 kcal; F2 = 1.348, p = 0.28).

Conclusions
Concussed student-athletes appear to have suppressed resting metabolism of about 40% following injury when compared with validated prediction equations. Although future studies are needed to confirm our findings by comparing concussed participants to healthy-matched controls, these preliminary data suggest use of prediction equations to estimate concussed student-athletes' dietary energy requirements should be used with caution.

Disclosures: Dr. Walton has nothing to disclose. Dr. Bernitt has nothing to disclose. Dr. Daniell has nothing to disclose. Dr. Malin has nothing to disclose. Dr. Resch has nothing to disclose.

Catching the snitch or the consequences? Profiling incidence of concussions in Quidditch players

Vi Tran; Spencer Walser; Jeff Wayland; Adam Elwood; Jose H. Posas, MD

Background

Concussions are caused by a blow to or a violent shaking of the head or body. With increasing popularity of novel sports, such as Quidditch inspired by the Harry Potter series, it is suspected that players are commonly misdiagnosed or not seeking treatment after suffering a concussion. Here, we look at the incidence of concussion in Quidditch players.

Materials/methods

After obtaining IRB approval we conducted an anonymous cross-sectional survey amongst players in the Major League Quidditch for the 2017 season. The survey included questions corresponding to demographics, previous medical history specific to concussions, migraines, co-morbidities, and suspected concussions whilst engaging in Quidditch.

Results

Four hundred sixty-four players were contacted via email with 34% response rate. Of 34%, 96.2% previously engaged in sports either high school or collegiate level. Twenty-six percent of males and 29% of females reported having previously medically diagnosed concussions outside of Quidditch. Fifteen percent reported never hitting their head during a Quidditch match while 19% indicated more than 10 total head injuries. Twenty-five percent of players reported a medically confirmed concussion during play, with 20% indicating a suspected concussion without medical evaluation. Thirty-four percent reported a history of depression or anxiety with 21 players reporting a history of migraines. Those with confirmed head injuries or suspected concussion, 39% indicated that they sought medical treatment while 24% responded that they did not.

Conclusion

Majority of Quidditch players reported having suffered a concussion prior to playing while half reported suffering a confirmed or suspected concussion during a game. Players were divided on seeking treatment. It is well documented that history of migraines or other comorbidities combined with multiple concussions leads to longer recovery times as well as higher rates of post-concussive syndrome. With the growing rate of traumatic brain injuries, it is imperative that players are diagnosed and treated to prevent future consequences.

Disclosures: Dr. Tran has nothing to disclose. Dr. Walser has nothing to disclose. Dr. Wayland has nothing to disclose. Dr. Elwood has nothing to disclose. Dr. Posas has nothing to disclose.

Neuro-visual miscalculations in acute mTBI

Abby Wicks; James A. Black, MD; Matthew Donald Holtkamp, MD

Objective

To describe oculomotor abnormalities following acute mild traumatic brain injury (mTBI) as a possible target for Rehabilitation.

Background

More than 361,092 service members have sustained mTBI between 2000 and 2016.82.4 percent being mTBI. The vast majority improve within a few weeks. However, small percentages continue to have symptoms of Chronic TBI, including those with objective findings on oculomotor exam. The neuropathology of these finding are well documented and are possible targets of acute mTBI rehabilitation. This case series explores the typical finding of symptomatic patients after mTBI. Neuro-optometry is a subspecialty which evaluates the visual system for dysfunction following neurologic insult. Binocular dysfunction is prevalent following mTBI. Recent literature supports the hypothesis that the visual system can be utilized to evaluate the extent of brain injury. The NSUCO oculomotor test allows for quantification of saccadic and pursuit inaccuracies.

Methods

The case series reported here from the Intrepid Spirit Center (ISC), Fort Hood focuses on the treatment of acute mTBI patients referred by primary care providers or emergency departments. Three military service members with acute mTBI underwent a complete neurologic examination with a neurologist, including an oculomotor function assessment with a Neuro-optometrist utilizing the NSUCO oculomotor test (video attached).

Results

We have video documentation demonstrates typical oculomotor dysfunction seen in acute mTBI patients, including poor initiation of saccades, inaccurate spatial planning and execution of saccades, and fixation losses on pursuits on binocular assessment.

Conclusion

Oculomotor dysfunction is a verifiable, reproducible documentation of organic dysfunction in acute mTBI amenable to therapeutic approaches including neuro-optometric visual rehabilitation. Neuro-optometric vision rehab is a novel treatment modality for acute mTBI.

Disclosures: Dr. Wicks has nothing to disclose. Dr. Black has nothing to disclose. Dr. Holtkamp has nothing to disclose.

Y-Balance test asymmetry is greater in collegiate athletes with a history of concussion

Matthew Hoch; Nicole Curry; Emily Hartley-Gabriel; Nicholas Heebner; Johanna Hoch

Athletes with a history of concussion (HC) are at an increased risk of sustaining lower extremity injuries. It is unclear if these individuals exhibit dynamic postural control deficits associated with lower extremity injury risk. The purpose of this study was to determine if collegiate athletes with a HC demonstrate differences in Y-Balance Test (YBT) performance compared to athletes with no history of concussion (NHC). A total of 116 varsity and club athletes from a Division-I university participated. Forty participants reported a HC (female/male: 31/9, age: 20.0 ± 1.4 years, height: 169.3 ± 13.1 cm, mass: 68.4 ± 14.0 kg) while 76 reported NHC (female/male: 60/16, age: 20.0 ± 1.7 years, height: 168.5 ± 12.9 cm, mass: 68.7 ± 14.6 kg). Individuals with a current concussion or lower extremity injury, or a history of lower extremity surgery were excluded. Participants completed the YBT anterior reach direction barefoot on both limbs. The YBT was completed by maximally reaching anteriorly, maintaining balance, and returning to the starting position without errors. Participants completed 4 practice trials and 3 test trials. Reach distances were averaged and normalized to leg length. Between-limb asymmetry was calculated as the absolute difference between the left and right limbs. Separate independent t-tests examined group differences in normalized reach distances and asymmetry. The proportion of participants in each group with >4 cm of asymmetry was compared using a χ^2 test. Alpha was set at 0.05 for all analyses. No group differences were identified in normalized reach distances for the left (HC: 61.4% ± 9.2%, NHC: 60.8% ± 6.2%, $p = 0.88$, ES = 0.08) or right (HC: 61.4% ± 6.2%, NHC: 60.2% ± 6.8%, $p = 0.51$, ES = 0.17) limbs. However, a greater proportion of HC participants demonstrated >4 cm asymmetry (HC: 40.0%, NHC: 19.7%; $p = 0.02$) and these participants exhibited greater asymmetry (HC: 3.87 ± 3.69 cm, NHC: 2.40 ± 2.13 cm, $p = 0.03$; ES = 0.53). Athletes with a HC exhibited greater asymmetry compared to athletes with NHC. Anterior reach asymmetries of >4 cm are associated with greater lower extremity injury risk. The YBT may provide a clinical technique to further explore the relationship between concussion and lower extremity injury.

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The effects of submaximal aerobic exercise on heart rate variability in adolescent athletes with history of concussion

Brett Steven Gunn; Adam T. Harrison; R. Davis Moore

The purpose of this study was to evaluate cardio-autonomic regulation in adolescent athletes with and without history of concussion, at rest and following moderate intensity aerobic exercise. We hypothesized that exercise would reveal covert impairments in cardio-autonomic function for athletes with a history of concussion following aerobic exercise. Male adolescent hockey players were recruited and divided into history of diagnosed concussion and matched controls without history of concussion. Athletes in the concussion group were 3 + months from injury, asymptomatic, and currently engaged in sport. Cardio-autonomic function was measured for 5-minute at rest, and for 10-minute following cycle ergometry at 60%–70% theoretical maximal heart rate. Variable evaluated were mean normal-normal interval (mean NN), standard deviation of NN intervals (NN), root mean square of successive differences (RMSSD), low frequency (LF), high frequency (HF) and approximate entropy (ApEn). No differences were observed between those with and without a history of concussion at rest. However, the concussion group showed significant differences in mean RR interval and approximate entropy following exercise relative to matched controls ($p = 0.05$). Moderate intensity exercise may induce cardio-autonomic dysfunction in adolescent athletes with a history of concussion, even after they are asymptomatic and make a full return to play. These findings support prior reported findings that exercise can induce a decoupling between the autonomic and cardiovascular systems following concussion.

Propagating prion-like amyloid proteins invade target cells through endocytic vesicle rupture

William Patrick Flavin; David Freeman; Luc Bousset; Zachary Green; Yaping Chu; Jeffrey Kordower, PhD; Ronald Melki; Edward Campbell

Numerous pathologic amyloid proteins spread from cell to cell during neurodegenerative disease, facilitating the propagation of cellular pathology and disease progression in a prion-like fashion. Understanding the mechanism by which amyloid assemblies enter target cells and induce dysfunction is therefore key to understanding the progressive nature of diseases like Alzheimer's, Parkinson's, Huntington's, and chronic traumatic encephalopathy. In this study, we utilized an imaging-based assay to monitor the ability of amyloid assemblies to induce the rupture of intracellular vesicles following endocytosis, as well as to elucidate the cellular consequences of this damaging mechanism of invasion. We observe that induction of vesicle rupture is a conserved ability of fibrillar amyloid assemblies of alpha-synuclein, tau, and polyglutamine-rich huntingtin. Endocytic vesicle rupture potency is strongly influenced by strain conformation and is increased by assembly phosphorylation. Vesicles ruptured by alpha-synuclein can accumulate and fuse into large, intracellular structures resembling Lewy bodies in vitro, and the same markers of vesicle rupture surround Lewy bodies in brain sections from Parkinson's patients. Finally, ruptured vesicles containing alpha-synuclein can be observed in the extracellular environment and can be seen trafficking from cell to cell. These data underscore the importance of endocytic vesicle rupture as a conserved mechanism of cellular invasion by multiple disease-associated amyloid protein assemblies, implicate this process in the formation of proteinaceous inclusions such as Lewy bodies, and suggest that this form of cellular damage can serve as both a driving force and a vector for amyloid protein release and subsequent transmission to neighboring cells.

Mood alterations in concussed university athletes who made a complete return to play

William Sauve; Robert Moore; Dave Ellemberg

Affective disorders such as depression are now estimated by the WHO to be the greatest cause of disability worldwide (Mathers et al., 2006). Brain research into affective dysregulation suggest that the prefrontal cortex plays a particular role in the regulation of affect (Johnstone & Walter, 2014) One common injury of the prefrontal cortex is concussion, which accounts for 70%–90% of all brain injuries(Cassidy et al., 2004). Most of the literature related to the consequences of concussion is cross-sectional, which mean that it is difficult to clearly identify a cause and effect relationship (Caruana et al., 2015). The purpose of this study was to assess the mood states of university athletes before a concussion and during the acute phase of the injury. As such, 15 collegiate athletes (age = 20.87 ± 1.92) completed the Beck's Depression Inventory-II (BDI-II) and the Profile of Mood States (POMS) at baseline (73.40 ± 34.33 days prior to a concussion) and on average 6 days following a concussion after making a complete return to play. On the POMS subscales, athletes reported lower vigor ($p = 0.03$) at day 6 (12.47 ± 4.81) compared to their preinjury score (14.60 ± 3.79). Athletes also reported greater intensity of depressive symptoms on the total score of the BDI-II ($p = 0.05$) at day 6 (7.33 ± 8.15) compared to their preinjury score (4.53 ± 4.29). A trend was also observed ($p = 0.08$) on the somatic subscale of the BDI-II where athletes reported greater somatic symptoms following a concussion (4.27 ± 3.97) compared to pre-concussion (2.87 ± 2.61). Although the current results do not suggest concussions lead to clinically significant mood alterations, they do support subtle mood alterations selective to vigor and depression.

History of undiagnosed concussion is associated with concussion-like symptoms following subconcussive head impacts

Jaclyn B. Caccese, PhD; Fernando Vanderlinde Santos; Mariana Gongora; Ian Sotnek; Elizabeth Kaye; Felipe Yamaguchi; John Jeka

Objective

Immediate removal from activity after sport-related concussion is associated with less time missed from sport, a shorter symptomatic period, and better outcomes on acute clinical measures than delayed removal from activity. However, the effects of undiagnosed concussion on clinical outcomes have not been studied. In the case of an undiagnosed concussion, when the athlete is not removed from play, he/she may undergo subsequent repetitive head impacts. Subsequent head impacts may prevent complete recovery and make the athlete more sensitive to even mild mechanical head impact. The purpose of this study was to determine if soccer players with a history of undiagnosed concussion are more likely to report concussion-like symptoms following typical soccer heading than those without a history of undiagnosed concussion.

Methods

Thirty-one adult amateur soccer players (17 males and 14 females, 22.3 ± 4.5 years, 171.0 ± 9.2 cm, 71.9 ± 11.4 kg) completed a self-reported concussion/sport history questionnaire as part of a larger study

aimed to identify behavioral and biomarkers of subconcussion. Participants were asked to report diagnosed and undiagnosed concussions. Undiagnosed concussions consisted of unreported and unrecognized concussions. Participants also indicated concussion-like symptoms typically experienced after soccer heading. A χ^2 analysis was used to determine if a history of undiagnosed concussion was associated with prolonged concussion-like symptoms following subconcussive head impacts.

Results

Individuals with a history of undiagnosed concussion were more likely to report concussion-like symptoms following soccer heading (χ^2 = 5.114, p = 0.024; Likelihood Ratio = 4.693, p = 0.030).

Conclusions

The results of this study suggest that individuals who experience unreported or unrecognized concussions may be more likely to experience concussion-like symptoms following repetitive subconcussive head impacts and highlight the importance for athletes in immediately reporting concussion signs and symptoms. We speculate that these individuals may not fully recover and may remain sensitive to mild mechanical head impact even years following their concussion.

Head impact burden and change in neurocognitive function over 2 seasons of youth football participation

Sean C. Rose, MD; Keith Yeates; Matthew T. McCarthy, MD; Darren R. Fuerst; Patrick Ercole; Joseph Nguyen; Natalie Pizzimenti

Objective

To determine the association of repetitive sub-concussive head impacts with neurocognitive outcomes in primary school and high school tackle football players.

Methods

We conducted a prospective cohort study of 35 primary school players age 9–12 and 20 high school players age 15–18 who each participated in 2 consecutive seasons of tackle football from 2016 to 2017. Helmet-based sensors were used to record head impacts during contact practices and games, which were summed as a cumulative impact for the 2 football seasons. Players were also divided into high intensity and low intensity groups based on whether they sustained high g-force impacts in both seasons. Players completed assessments on a variety of outcomes before the 2016 season and after the 2017 season: neuropsychological test performance, symptom ratings, vestibular-ocular function, balance, parent-completed ADHD symptoms, and self-reported behavioral adjustment.

Results

Average cumulative impact was 6,920 (SD 4,553) g-forces combined for the 2 seasons and did not differ between age groups (p = 0.66). Twenty-one players (38%) were classified as high intensity based on individual impacts. After correcting for multiple comparisons, neither cumulative impact nor impact intensity predicted change scores from pre-2016 season to post-2017 season on any outcome measures. Instead, younger age group and history of ADHD predicted worse change scores on several cognitive measures and ADHD symptom reporting.

Conclusions

Over 2 consecutive seasons of primary and high school tackle football participation, cumulative head impact burden and intensity of impacts were not found to be associated with changes in cognition, balance, vestibular-ocular function, or behavioral adjustment.

Greater exposure to repetitive subconcussive head impacts is associated with vestibular dysfunction and balance impairments during walking

Fernando Santos; Jaclyn B. Caccese, PhD; Mariana Gongora; Ian Sotnek; Elizabeth Kaye; Felipe Yamaguchi; John Jeka

Exposure to repetitive subconcussive head impacts (RSHI), specifically soccer heading, is associated with white matter microstructural changes and cognitive performance impairments. However, the effect of soccer heading exposure on vestibular processing and balance control during walking has not been studied. Galvanic vestibular stimulation (GVS) is a tool that can be used to probe the vestibular system during standing and walking. The purpose of this study was to investigate the association of soccer heading with subclinical balance deficits during walking. Twenty adult amateur soccer players (10 males and 10 females, 22.3 ± 4.5 years, 170.5 ± 9.8 cm, 70.0 ± 10.5 kg) walked along a foam walkway with the eyes closed under 2 conditions: with GVS (~40 trials) and without GVS (~40 trials). Outcome measures included mediolateral center-of-mass (COM), center-of-pressure (COP) separation, foot placement, mediolateral ankle modulation, hip adduction, and ankle push off. For each balance mechanism, a GVS response was calculated (GVS, mean [without GVS]). In addition, participants completed a questionnaire, reporting soccer heading exposure over the past year. A linear regression model was used to determine if vestibular processing and balance during walking were related to RSHI exposure. Both foot placement ($R2$ = 0.324, p = 0.009) and hip adduction ($R2$ = 0.183, p = 0.50) were predicted by RSHI; whereby, greater exposure to RSHI was associated with greater foot placement and hip adduction responses. However, COM-COP separation ($R2$ < 0.001, p = 0.927), ankle modulation ($R2$ = 0.037, p = 0.417), and push off ($R2$ < 0.001, p = 0.968) were not related to RSHI exposure. Individuals who were exposed to greater RSHI were more perturbed by vestibular stimulation during walking, suggesting that there may be vestibular dysfunction and balance impairments with frequent heading; specifically, individuals with greater exposure to RSHI responded with larger foot placement and hip adduction responses to GVS.

Attention deficit hyperactivity disorder increases anxiety and depression in concussed college athletes

Brett Steven Gunn; Jacob James Michael Kay, MS; Toni Torres-McGehee; Davis Moore

The purpose of this study was to compare symptom profiles of anxiety and depression in athletes with ADHD, a history of concussion, a history of concussion and ADHD, and controls. We hypothesized collegiate athletes with ADHD who experienced a concussion would report higher levels of anxiety and depression than other athletes. Nine hundred seventy nine NCAA Division-I college athletes at the University of South Carolina (USC) were surveyed as part of a larger performance health and wellness management program at USC. We acquired ADHD diagnoses, history of concussion, physician diagnosed concussions, State-Trait Anxiety Inventory (STA-I), and Center of Epidemiologic Studies Depression Scale (CES-D). Athletes were divided into 4 groups (1) ADHD with Concussion, (2) ADHD no concussion, (3) ADHD no

concussion, and (4) No ADHD no concussion for comparison. State Anxiety scores were significantly higher in the ADHD with concussion group (42.1 ± 14.2) compared to all other groups (33.4 ± 8.9). Depression scores were also significantly higher for ADHD with concussion group (25.5 ± 10.2) than all other groups (16.3 ± 5.7). Tukey post hoc revealed both the anxiety mean difference of 8.4 (95% CI [0.68–6.2]) and depression mean difference of 9.7 (95% CI [4.2–15.1]) were statistically significant ($p < 0.05$). These findings suggest ADHD may have a cumulative effect on state anxiety and depression beyond that of either ADHD or concussion alone. Therefore, athletes with ADHD should receive extra care and management as they will likely experience more severe symptoms following injury.

Disclosures: Dr. Gunn has nothing to disclose. Dr. Kay has nothing to disclose. Dr. Torres-McGehee has nothing to disclose. Dr. Moore has nothing to disclose.

Abnormal respiratory patterns in a series of post-concussive patients

Karissa Arca, MD; Brent P. Goodman, MD; Amaal J. Starling, MD

Background
Autonomic nervous system dysfunction has been identified in patients following traumatic brain injury (TBI), including concussion. Abnormal postural heart rate and blood pressure instability have been identified in post-concussive patients. Recently, we have identified abnormal respiratory patterns during autonomic testing for post-concussive symptoms. Tachypnea is a clinical feature of autonomic instability in paroxysmal sympathetic hyperactivity following severe TBI and the purpose of this study is to identify abnormal respiratory patterns in patients with autonomic nervous system impairment following mild TBI.

Methods
A retrospective review of patients in the Mayo Clinic Arizona Concussion Program from October 2017 to March of 2018 was performed. Clinical features and autonomic testing were reviewed. Autonomic testing included blood pressure and heart rate responses to Valsalva, heart rate variability during deep breathing, blood pressure and heart rate responses to head-up tilt, sudomotor testing, and respiratory responses using respiratory inductive plethysmography. Patients with co-morbidities or medications with potential to influence autonomic testing were excluded.

Results
Fifteen patients with a history of concussion were studied. Nine of 15 patients had abnormal cardiovascular responses on autonomic testing, typically excessive postural tachycardia with head-up tilt. Abnormal respiratory patterns were identified in 8 of 9 patients with abnormal autonomic testing and in 3 of 6 patients without other abnormalities on autonomic testing. A number of different respiratory patterns were identified including tachypnea, prolonged apneic episodes, Cheyne-Stokes, and other unusual respiratory patterns.

Conclusion
We have identified abnormal respiratory patterns in a series of concussion patients with or without other signs of dysautonomia. Tachypnea has been previously reported as a clinical feature of paroxysmal sympathetic hyperactivity following severe TBI and was present in some patients in this series. The clinical significance and mechanisms involved in the generation of respiratory dysrhythmia require further study, but may be another manifestation of post-concussive dysautonomia.

Disclosures: Dr. Arca has nothing to disclose. Dr. Goodman has nothing to disclose. Dr. Starling has received personal compensation for consulting, serving on a scientific advisory board, speaking, or other activities with Eli Lilly & Company, eNeura, Alder, and Amgen.

Symptom-based clinical profiles in the classification of post-traumatic headache

Andrew H. Ahn, MD, PhD; Sylvia M. Lucas, MD, PhD

There are currently no established therapies for post-traumatic headache (PTH). One key obstacle standing in the way of meeting this unmet need is the fundamental gap in our understanding of the clinical course and functional impact of PTH. In this presentation we examine the existing schema used to characterize the clinical characteristics of PTH, including the International Classification of Headache Disorders (ICHD), and find that they leave major unresolved questions about the diagnosis, classification, and measurement of the clinical impact of PTH. Specifically, current data suggest that the ICHD classification, which is based on the extent of brain injury and the duration of condition, have limited prognostic and treatment implications. There are several challenges to the classification of PTH, as the clinical manifestations of PTH do not map well to the primary headache disorders, and the definition of the continuous and chronic daily headache require further study. Importantly, the existing classification do not provide or imply specific outcome measures for PTH, again a fundamental roadblock to testing therapeutic hypotheses for PTH. We hypothesize that a symptom-based classification is needed to begin an examination of these unresolved questions, and to establish clinically relevant endpoints for research and clinical trials for effective therapies.

Disclosures: Dr. Ahn has received personal compensation for activities with Eli Lilly & Co. as an employee. Dr. Lucas has received personal compensation for activities with Allergan, Zogenix, Allozyne, Kineta, Wadsworth Foundation, Biogen, and Genzyme as a speaker and/or an advisor.

Migraine with aura is the predominant phenotype among acute post-traumatic headache in sports

Tad Seifert, MD

Introduction
Headache is the most common symptom after traumatic brain injury (TBI), a global health concern with an estimated 2.5 million people in the United States reporting TBI in a single year. Regrettably, there is little evidence on the medical management of post-traumatic headache (PTH). Generally, treatment is approached as the primary headache disorder it most closely resembles in phenotype. In the lay public, the majority of PTHs exhibit migraine or probable migraine characteristics; however, PTH phenotypes within a sporting context have not been reported.

Methods
This cross-sectional survey evaluated the characteristics of headache in 102 student-athletes, ages 13–23 who had sustained sport-related concussion. Acute post-traumatic headache and sport-related concussion were defined by the International Classification of Headache Disorders and the Concussion in Sport Group definitions, respectively. The sample included male and female athletes from a variety of sports, with differing degrees of contact exposure. The survey collected data on personal and family history of headache, as well as specific headache characteristics.

Results
The study included 54 males and 48 females. Migraine with aura (45.4%) was the predominant phenotype is this cross sectional cohort of sport-related acute post-traumatic headache. This was followed by migraine without aura (22.7%), tension-type headache (21.8%), and other (10.1%).

Conclusions

Migraine with aura is a common phenotype among sport-related acute PTH. Further studies should evaluate for potential differences in recovery trajectories when compared to other headache phenotypes.

Feasibility of smartphone-delivered progressive muscle relaxation (PMR) therapy in post traumatic headache (PTH) management

Saima Usmani; Sandra India Aldana; Mia T. Minen, MD; Emma Ortega

Background

Progressive muscle relaxation (PMR) has level A evidence in preventing migraine and tension-type headaches. However, there is limited research on behavioral therapy for post-traumatic headache (PTH) let alone delivered via a smartphone application.

Aims/objective

To gain preliminary evidence as to whether smartphone based PMR is feasible for subjects with PTH.

Method(s)

We performed a single-arm study of prospective patients calling our Concussion Center between June 2017 and May 2018. Subjects met ICHD-3 criteria for persistent headache secondary to mTBI, were age 18–85 and 3–12 months post injury, with no prior behavioral treatments for headache in the past year. We assessed prior and current headache and neuropsychologic histories. Using the RELAXaHEAD smartphone application, subjects were instructed to record headache symptoms daily and practice 20 minutes of PMR daily. There was a 1-month follow-up assessment.

Results

In our ongoing study, 21 subjects are currently enrolled, 13 female (62%) with mean age 41.4 (SD 13.1, range 20–65). Nine (43%) subjects had pre-existing headaches. Subjects' injuries were on average 6 months prior to enrollment (SD 2.6, range 4–12). Three (14%) were sports-related. In the month prior to enrollment, subjects reported 19.3 headache days (SD 8.76, median 20, range 5–30). 17 (81%) subjects reported memory problems and 18 (86%) reported impaired concentration. Of 17 subjects enrolled for at least 1 month, 9 (53%) imputed data for 20 or more days within the first month (mean 17 days, SD 12.2, median 20, range 0–31). 4 (24%) practiced PMR 2 + times/wk (mean 8.4 days, SD 8.6, median 6, range 0–31).

Conclusion

PTH subjects' obstacles regarding adherence to mHealth technology should be further assessed before PMR efficacy can be assessed. Notably, many subjects concurrently reported difficulties with memory and concentration, which may be contributing to poor adherence. Future work will attempt to assess for differences among users vs non-users.

Early prophylactic treatment reduces development of chronic post traumatic headache after concussion

Ian Crain, MD; Justin Hoskin, MD; Yazan Al-Hasan, MD; Glynnis Zieman, MD; Javier Cardenas, MD

Background

Headaches after concussion are common, potentially debilitating, and long lasting. There are currently no guidelines on the treatment of post traumatic headaches (PTH). The aim of this study is to investigate the effects of early prophylactic pharmacologic treatment on the development of chronic post traumatic headaches (cPTH) in adolescent and adult concussion patients.

Methods

Patients were retrospectively enrolled from the patient population at the Barrow Concussion and Brain Injury Center (Phoenix, AZ) from the previous 5 years. Males and females ages 13 and older with a diagnosis of PTH attributed to mild head injury based on ICHD2 criteria who were offered a headache prophylactic medication were included. Patients were divided into 3 groups: those who did not take treatment (Untreated), those who took nortriptyline (Nor), and those who took topiramate (Top). Groups were subdivided into those that developed cPTH and those who did not (ncPTH). The average time from injury to start of treatment (SoT) in days were analyzed using t-tests within and between groups.

Results

One hundred twenty patients met inclusion criteria for the study (Untreated = 36, Top = 46, Nor = 38). Overall, 64 of 120 patients met criteria for cPTH (53%). SoT and development of cPTH is significant overall (35 vs 23, $p < 0.001$). SoT is significant for Untreated (NcPTH 14.4 vs cPTH 35.6, $p = 0.001$) and Top (NcPTH 23.9 vs cPTH 35.5, $p = 0.002$), but not for Nor (NcPTH 31.9 vs cPTH 34.0, $p = 0.372$). For NcPTH there is a significant difference between SoT for Untreated and Top (14.4 vs 23.9, $p = 0.04$) and Untreated vs Nor (14.4 vs 31.9, $p = 0.002$), but not Top and Nor (23.9 vs 31.9, $p = 0.09$). For cPTH there is no difference for SoT between groups.

Conclusion

Early intervention with nonpharmacologic treatments and topiramate is associated with reduced development of cPTH.

Child Neurology Society survey of practitioners on management of pediatric post-traumatic headache

Desiree Levyim, MD; Rachel Pearson, MD; Raquel Leanne Langdon, MD; Sharief Taraman, MD; Meeryo Choe, MD

Background

Traumatic brain injury (TBI) is a significant cause of morbidity in the pediatric population with headache being the most common post-concussive symptom. There are no established guidelines for the management of pediatric post-traumatic headache (PTH). This study aimed to better characterize common clinical practices of child neurologists in order to guide additional research in this area.

Methods

Members of the Child Neurology Society were surveyed.

Results

Ninety five practitioners responded to the survey. Respondents were heterogeneous in their experience and practice setting; 33.7% of respondents evaluated less than 25 pediatric concussion patients per year, 40.0% evaluated 25–50, and 26.3% saw >50 per year. The majority saw patients with subacute to persistent, mild TBI. 38.9% of practitioners reported that they consistently use the International Classification of Headache Disorders (ICHD) criteria to diagnose pediatric PTH, however only 18.9% correctly defined PTH as persistent at 12 weeks, as per ICHD classification. A majority of respondents recommended NSAIDs as abortive therapy after PTH, but instructions regarding timing after injury and frequency of use varied. The time-after-injury when prophylactic headache medication was recommended also varied;

one-third considered prophylaxis within 1 month and one-third between 1 and 2 months. The medications most commonly used for prophylaxis were amitriptyline (93.7%), topiramate (71.6%), and vitamins/supplements (58.9%). Injection-based therapies were used by 38.0%. 93.7% recommended non-medical treatments, and 38.0% recommended injection-based therapies. Prescriptions for cognitive and physical rest and return to play were also variable; one-third of respondents recommended cognitive and physical rest for 1–3 days followed by progressive return to cognitive and physical activities, which is consistent with current guidelines.

Conclusions

As there are no established guidelines on management of PTH, it is not surprising that diagnosis and management varies considerably. Further studies are needed to define the best, evidence-based practices for pediatric PTH.

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Biomechanical comparison of concussions with and without a loss of consciousness in elite American football

Janie Cournoyer and Thomas Blaine Hoshizaki

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