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Differential Effect of First versus Second Concussive Episodes on Wavelet Information Quality of EEG

Semyon Slobounov^{*}, Cheng Cao^{*}, and Wayne Sebastianelli^{**}

^{*}The Department of Kinesiology, The Pennsylvania State University, USA

^{**}Athletic Medicine Clinic, The Pennsylvania State University, USA

Abstract

Objective—Recent reports have suggested that long-term residual brain dysfunctions from mild traumatic brain injury (MTBI) that are often overlooked by clinical criteria may be detected using advanced research methods. The aim of the present study was to examine the feasibility of EEG wavelet information quality measures (EEG-IQ) in monitoring alterations of brain functions as well as to determine the differential rate of recovery between the first and second concussive episodes.

Methods—Student-athletes at high risk for MTBI (n=265) were tested prior to concussive episodes as a baseline. From this subject pool, twenty one athletes who suffered from two concussive episodes within one athletic season and were tested on days 7, 14 and 21 post-first and second injuries using a within-subjects design. Specifically, EEG was recorded and processed using wavelet entropy (EEG-IQ) algorithm along with a battery of neuropsychological (NS) tests. Spatial distribution of EEG-IQ and its dynamics in conjunction with NS data were analyzed prior to and after MTBI.

Results—No neuropsychological deficits were present in concussed subjects beyond 7 days post-injury after first and second concussions. However, EEG-IQ measures were significantly reduced primarily at temporal, parietal and the occipital regions (ROIs) after first and especially after second MTBI ($p < 0.01$) beyond 7 days post-injury. Rate of recovery of EEG-IQ measures was significantly slower after second MTBI compared to those after the first concussion ($p < 0.01$).

Conclusions—EEG-IQ measures may reveal alterations in the brain of concussed individuals that are most often overlooked by current assessment tools. In this regard, EEG-IQ may potentially be a valuable tool for assessing and monitoring residual brain dysfunction in “asymptomatic” MTBI subjects.

Significance—The results demonstrate the potential utility of EEG-IQ measures to classify concussed individuals at various stages of recovery.

Keywords

MTBI; EEG Information Quality (EEE-IQ); Wavelet Entropy; Differential Recovery after MTBI

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Corresponding Author: Dr. Slobounov, 268 Recreation Building, University Park, PA 16802, Phone: (814) 865 3146; Fax: (814) 863 7360; Email: sms18@psu.edu.

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1. Introduction

Mild traumatic brain injury (MTBI), commonly known as a “concussion” is still one of the least understood athletic injuries. One of the main issues with respect to concussions is that with the exception of the unconscious individual or someone who is severely disoriented, it is often very difficult to identify who has sustained a concussion and who has not (Cantu, 2006). Attempts to classify concussion as a traumatic event based upon clinical symptoms at the site of injury may be erroneous. Advanced research methods may detect both behavioral (e.g., abnormal balance see: Cavanaugh et al., 2005, 2006; Slobounov et al., 2007; 2008) and neural (e.g., abnormal EEG/MRS records, Thatcher, 1989; Slobounov et al., 2002, 2006; Bluml & Brooks, 2006) residual deficits far beyond the early post-injury 10 days period.

Recently, *entropy* or information based analyses of EEG signal have been introduced (Rosso et al., 2001; Shin et al., 2006). Assuming that the entropy is an approximate measure of the signal or neuron activity complexity (Pincus, 1991), it has been suggested that a larger information content of the brain oscillatory processes may be associated with better neurological brain status (Shin et al., 2006). Specifically, Rosso et al. (2001) proposed that wavelet entropy can be used for detecting functional abnormalities in the brain based on an analysis of short duration brain electrical signals. It has also been reported that the rate of change of wavelet entropy may be used to monitor global brain ischemia (Al-Nashash & Thakor, 2005; Al-Nashash et al., 2003). It was shown that wavelet entropy tends to drop rapidly during the ischemic stage of injury and increase during the recovery stage and, therefore, may provide advanced diagnostic instrumentation for brain injuries (Thakor & Tong, 2004). There is also additional evidence that indicates that there is a decrease of wavelet entropy in epileptic patients compared to age-matched normal controls (Hornero et al., 2003; Rosso et al., 2003).

More recently, a novel approach to estimate the amount of information contained in the EEG signal, called *Information Quality of EEG* (EEG-IQ¹), has been proposed by first applying discrete wavelet transform (DWT) to the EEG signal and then calculating the traditional Shannon Entropy (Shannon, 1948, SE) of the wavelet coefficients (Shin et al., 2006). The discrete wavelet transform (DWT) can be used to effectively reduce the redundancy of the predictable components of the EEG signal in all frequency bands of clinical interest.

There are several recent reports indicating that the EEG-IQ can be considered as a unified measure of entropy applicable to signal analyses in both time and frequency domains. The reduction in EEG-IQ associated with cardiac arrest in rats has been reported during pre- and post- arrest assessment, whereas these are not detected by traditional Shannon Entropy (SE) measures (Shin et al., 2006). This report is consistent with several other animal studies clearly demonstrating reduction of EEG-IQ as a result of abnormal brain functioning due to cardiac arrest (Koenig et al., 2006; Jia et al., 2006).

To our knowledge, there are no reports in the literature confirming robust modulation of EEG-IQ in human subjects suffering from traumatic brain injuries (TBI). Accordingly, in this study, we expanded previous research on EEG-IQ in animal models to the population of human subjects suffering from MTBI. Specifically, we examined dynamic modulation of EEG-IQ in athletes suffering from sport-related mild traumatic brain injuries (MTBI). It is hypothesized that if EEG-IQ is a sensitive measure of brain function, there will be both: (a) a localized differential alteration of this measure as a function of 1st versus 2nd MTBI; and (b) a differential dynamics of EEG-IQ resolution after 1st versus 2nd concussive episodes. Moreover, one of the novel features of our approach is an attempt to quantify the spatial distribution of EEG-IQ

¹It should be noted that EEG-IQ has nothing to do with “Intelligence Quotient”

values prior to and after MTBI rather than focusing on separate brain regions of interest (ROI) in isolation.

2. Method and Materials

2.1. Subjects

A total of 265 subjects were initially recruited (baseline testing) for this sport-related concussion study. All subjects were Pennsylvania State University athletes at high risk for traumatic brain injury (collegiate rugby, football, ice hockey and soccer players), aged between 18 and 25 years, male ($n=180$, mean age = 21.3 years) and female ($n=85$, mean age = 20.8 years). None of these subjects had a concussion history at the time of baseline testing. In this report we included data from subjects who met all of the following inclusion criteria: (a) suffered 2 concussive episodes within an athletic season; (b) suffered the first concussion within 12 months after baseline testing; (c) both concussive episodes were grade 1 MTBI (Cantu Data Driven Revised Concussion Grading Guideline, 2006); (d) the second concussion was not within 21 days of the first concussion; (e) neuropsychological (NS) and EEG data were available from baseline testing and from 3 consecutive follow-up testing after both 1st and 2nd MTBI. Twenty-one of the subjects from the total subject pool met all of the inclusion criteria and their data are included in this report.

After each concussion, subjects were tested on days 7, 14 and 21 post-injury. As mentioned in the inclusion criteria, none of the subjects who had a second concussion within 21 days of the first concussion were included in the analysis. Therefore, there was no overlapping in data collection between first and second concussions. The mean time period between the first and second concussive episodes was 45 days ($SD = 18$ days). All 21 subjects were clinically asymptomatic on day 7 after the first and second MTBI and were cleared for sport participation based upon neurological assessments (Co-operative Ataxia Rating Scale, World Federation of Neurology, Trouillas et al, 1997) as well as clinical symptoms resolution.

2.2. Neuropsychological Assessments

The neuropsychological tests were administered at baseline testing, within 48 hours after MTBI on day 7 and day 14 post-injury as standard paper and pencil tests for which the subject was seated at a table and were administered the test battery by the tester. The subject was instructed to complete the tests as quickly and accurately as possible. The NS testing battery consisted of three segments: Subjective Symptom Rating Scale (e.g., Penn State University Standard Concussion Rating Scale) to assess MTBI symptom severity; Symbol Digit Substitution test to assess information processing speed and working memory; Trails "B" test to assess information processing speed and scanning ability, (Randolph et al., 2001). The neuropsychological testing component lasted approximately 15 min.

2.3. EEG recording and processing

Subjects were seated with eyes closed in an electrically shielded and dimly lit environment. The continuous EEG was recorded using Ag/AgCl electrodes mounted in a 19-channel spandex Electro-cap (Electro-cap International Inc., Eaton, OH). The electrical activity from the scalp was recorded at 19-sites: FP1, FP2, FZ, F3, F4, F7, F8, CZ, C3, C4, T3, T4, T5, T6, PZ, P3, P4, O1, O2, according to the International 10–20 system (Jasper, 1958). The ground electrode was located 10% anterior to FZ, linked earlobes served as references and electrode impedances were below 5 kOhms. EEG signals were recorded using a programmable DC coupled broadband SynAmps amplifier (NeuroScan, Inc., El Paso, TX.). The EEG signals were amplified (gain 2500, accuracy 0.033/bit) with a recording range set for ± 55 mV in the DC to 70-Hz frequency range. The EEG signals were digitized at 1000 Hz using 16-bit analog-to-digital converters.

The EEG data were initially processed off-line using EEGLAB 5.03 (Delorme and Makeig, 2004) using Matlab open source toolbox (Mathworks, Natick, USA). Imported data were down sampled to 200 Hz to reduce computing time and epoched from 0 to 500 ms. After baseline normalization these epochs were automatically screened for unique, non-stereotypic artifacts using a probabilistic function within EEGLAB. This procedure allows the removal of epochs containing signal values exceeding 3 SD and controls for artifacts such as eye blinks, eye movements, heartbeats etc. Following this procedure at least 3 min of artifact free EEG signal were subjected to further analysis.

2.4. Discrete Wavelet Transform

The 1-level discrete wavelet transform of EEG signal $x[n]$ was calculated by: (a) passing the signal through a pair of quadrature mirror filters, $g[n]$ which is a low-pass filter and $h[n]$ which is a high-pass filter, and then (b) down sampling the outcome by 2:

$$\begin{aligned} y_{low}[n] &= \sum_{k=-\infty}^{\infty} x[k]g[2n-k] \\ y_{high}[n] &= \sum_{k=-\infty}^{\infty} x[k]h[2n-k] \end{aligned} \quad [1]$$

Where: $y_{low}[n]$ are the approximation coefficients and $y_{high}[n]$ are the detail coefficients. For n-level DWT, this process was repeated n times, the approximation coefficients of each level are decomposed with high and low-pass filters. The whole process can be represented as a binary tree (see also Figure 1), referred to as filter bank. Each node of the tree represents a subspace with different time-frequency localization.

2.5. Shannon Entropy

The Shannon entropy is a measure of the uncertainty associated with a random variable. The Shannon entropy of a random variable X that has n possible values $\{x_1, x_2, \dots, x_n\}$ is

$$H(\mathbf{x}) = -\sum_{i=1}^n p(x_i) \log \left(\frac{1}{p(x_i)} \right) \quad [2]$$

Where: $p(x)$ is the probability mass function of x ;

For the continuous case, assume we have m observables of X , and the values of these observables fall into N adjacent intervals $I_1, I_2, \dots, I_N$, the approximated Shannon entropy of X has the similar form as equation [3]

$$\begin{aligned} \tilde{H}(\mathbf{x}) &= -\sum_{i=1}^N p_i \log (1/p_i) \\ p_i &= \frac{n_i}{m} \end{aligned} \quad [3]$$

Where: n_i is the number of observables of which values fall into the interval I_i .

2.6. Information Quality

The information quality (EEG-IQ) of a signal s with n samples is the Shannon entropy of the n -level DWT coefficients of s .

$$IQ(s) = \tilde{H}(DWT_n(s)) \quad [4]$$

In our study to estimate the mean of IQ of the EEG signal $\mathbf{x}$ within a certain time duration L , a sliding average method was applied. The length of the sliding average window is n , and the slide step is m , $m \leq n$, in our research, $m=n$

$$E(IQ(x)) = \sum_{i=1}^l IQ(x_i) / l$$

$$l = 1 + (L - n) / m \quad [5]$$

Where: x_i is the EEG signal within the i th window; l is the number of the sliding windows. Since there were 6 decomposition levels of DWT, we have included only detailed coefficients into the computation of EEG-IQ. The approximation coefficients of the 6th level were excluded. Accordingly, the frequency band of the EEG-IQ computation ranged from 1.56 to 70 Hz.

2.7. Statistical analysis

In order to reduce the number of independent variables (e.g., the number of possible pairings) and to avoid the loss of statistical power we collapsed 19 EEG channels into 5 topographical regions of interest (ROIs), (similar to Oken & Chiappa, 1986; Kranczioch et al., 2008): frontal (Fp1, Fp2, Fz, F4, F3, F8, F7), temporal (T3, T4, T5, T6), central (C4, C3, Cz), parietal (Pz, P4, P3) and occipital (O1, O2). The EEG-IQ values were averaged within each ROI and subjected to further statistical analyses. In order to address the question of if there was any differential effect of the first versus second concussive episodes on EEG-IQ measures, we conducted a mixed model ANOVA within subject design using events ($n=3$, baseline testing, 1st concussion, and 2nd concussion) as a factor. The subject factor was treated as a random factor with 21 levels.

In order to quantify the dynamics of EEG-IQ (those at day 7, 14 and 21 post-injury) as a function of 1st versus 2nd concussive episodes, we conducted mixed model ANOVA design with polynomial contrast where the event factor was treated as a fixed factor with 2 levels. Where appropriate, we implemented Tukey's post-hoc tests. In addition, we conducted a linear Pearson correlation analysis between each MTBI subject's time period separating two concussive episodes and EEG-IQ differences (e.g., % change of EEG-IQ values between baseline and those at day 7 after 2nd concussion).

Finally, we conducted a mixed model ANOVA within subject design with polynomial contrast to assess: (a) effect of testing day; and (b) differential effect of 1st versus 2nd concussive episodes on NS values (i.e., Symbol Digit Distribution & Trails "B" testing). We implemented Tukey's post-hoc tests, when appropriate. The Minitab Inc. software package was used to conduct the statistical analysis.

3. Results

3.1. Neuropsychological testing

None of the subjects reported the symptoms of concussion (i.e., headache, light sensitivity, dizziness, memory & concentration problems, disorientation etc.) on day 7 after the first and/or second MTBI. Figure 2 illustrates the major findings of the NS Trails "B" testing. As can be seen from this figure, MTBI subjects' Trails "B" NS scores were reduced when obtained on 48 hours and on day 7 post-injury with respect to baseline testing. A similar trend was

observed when considering the Symbol Digit Substitution scores. There were no significant differences between NS testing scores (i.e., Trails “B” & Symbol Digit Substitution) obtained prior to injury (baseline testing) and on day 14 post-injury.

The ANOVA revealed a significant main effect of the testing date on Trails “B” scores, $F(3, 41) = 15.39, p < 0.01$, and on Symbol Digit Substitution scores, $F(3, 41) = 14.25, p < 0.01$. Post-hoc tests revealed that there were significantly less Trails “B” and Symbol Digit Substitution scores on 48 hours and on day 7 post-injury than those pre-injury ($p < 0.01$), while there were no significant differences between NS scores at baseline testing and those at day 14 post-injury. Moreover, there was no significant interaction between linear trend (i.e., evolution of NS symptoms) and events (i.e., 1st versus 2nd concussion), $p > 0.01$, indicating that NS symptoms resolution remained the same regardless of whether it was the first or the second concussive episode.

3.2. EEG-IQ: Effect of the First versus Second MTBI

The absolute values of EEG-IQ at five ROIs obtained during baseline testing and after concussive episodes at day 7 post-injury are shown in Table 1. As can be seen from this Table, EEG-IQ values were decreased after MTBI, predominantly at occipital, parietal and temporal ROIs after both concussive episodes. It should be noted, however, that this effect was more pronounced after the 2nd concussion.

The ANOVA revealed a significant main effect of event at occipital ($F[2, 41] = 179.18, p < 0.001$), parietal ($F[2, 41] = 181.98, p < 0.001$) and temporal ($F[2, 41] = 98.17, p < 0.001$) ROIs. The results of post-hoc testing revealed significant differences between EEG-IQ at baseline and those after 1st and 2nd concussion, $p < 0.001$. Finally, the differences between EEG-IQ values after 1st and 2nd concussion were also significant, $p < 0.001$.

3.3. EEG-IQ dynamics: first versus second MTBI

Differential dynamics of EEG-IQ values within 3 weeks post-injury as a function of 1st versus 2nd concussive episode is shown in Figure 3 a & b. As can be seen from this figure, there were lower values of EEG-IQ after 2nd MTBI than those after the 1st MTBI regardless of testing day. It is important to note that there are no obvious changes in EEG-IQ that were observed within 21 days after 2nd MTBI at occipital, temporal and parietal ROIs. The ANOVA revealed a significant linear trend for occipital, $F[1, 100] = 141.23, p < 0.001$, parietal, $F[1, 100] = 140.83, p < 0.001$, and temporal, $F[1, 100] = 108.96, p < 0.001$ ROIs. A significant main effect of the event was found for occipital, $F[1, 100] = 704.14, p < 0.001$, parietal, $F[1, 100] = 299.19, p < 0.001$ and temporal, $F[1, 100] = 438.19, p < 0.001$ ROIs. A significant interaction between linear trend and event was found also for occipital, $F[1, 100] = 49.76, p < 0.001$; parietal, $F[1, 100] = 36.67, p < 0.001$ and temporal, $F[1, 100] = 31.79, p < 0.001$ ROIs.

Finally, a linear Pearson correlation analysis revealed a significant inverse relationship between the time separating two concussive events (days) and percent change of EEG-IQ values from baseline data to those at day 7 post-2nd MTBI (see Figure 4). This was true for occipital ($r = -0.51, p = 0.005$), temporal ($r = -0.58, p = 0.004$) and parietal ($r = -0.55, p = 0.004$) ROIs. In other words, the shorter the time between the two concussive events, the larger the reduction of EEG-IQ values that were observed.

Discussion

There are several findings of interest from this report that will be discussed. *First*, neither clinical symptoms nor neurological deficits were present in MTBI subjects on day 7 post-injury, regardless of whether they suffered their 1st or 2nd concussive episode. Accordingly, all

concussed athletes under study were cleared for sport participation by clinical practitioners based upon neurological assessments as well as clinical symptoms resolution. *Second*, neuropsychological (NS) deficits including information processing speed, working memory, and scanning ability that were present at day 7 post-injury were resolved by day 14 post-injury. *Third*, we report a significant reduction of EEG-IQ values in athletes suffering from MTBI. This effect was most pronounced after the second concussion. Moreover, the time between two recurrent concussive episodes appeared to be an important factor influencing the amount of reduction in EEG-IQ values. *Fourth*, we report a differential rate of *recovery*- a.k.a. the EEG-IQ changed as a function of testing day and event indicating a better functional outcome after the first compared to the second concussion. *Finally*, the most pronounced impact of concussion in terms of alterations of EEG-IQ appeared to be at occipital, temporal and parietal ROIs. Overall, the results reported here suggest that EEG-IQ measures may be considered as a possible indicator of residual injury and/or functional brain recovery after MTBI.

There is still ongoing debate in the literature whether MTBI is a temporary functional abnormality in the brain or a long-term structural and functional deficit often overlooked by pure clinical assessment. Conventional wisdom mostly driven by neuropsychological (NS) data seems to suggest that athletes with uncomplicated and single MTBI experience rapid symptoms resolution within 1 to 2 weeks after the incident (Echemendia et al., 2001; Lovell et al., 2003). The NS data from this study are consistent with this commonly accepted notion demonstrating that neuropsychological signs as well as subjective symptoms were resolved in all subjects within 7 days regardless of the number of brain injuries.

The major results from this report may indicate the utility of the EEG-IQ measure as an indicator of functional brain alteration present beyond 7 days resulting from MTBI. To our knowledge this is the first report in humans demonstrating significant reduction of EEG-IQ measures (e.g., reduced complexity of neurological activity) in subjects suffering from MTBI. It should be noted that this effect was more pronounced when subjects have suffered their second concussion within the same athletic season.

Interestingly, the most significant differences in EEG-IQ prior to and after concussion came from the occipital, temporal and parietal areas. This finding is in agreement with the results of our recent EEG study indicating abnormal features in concussed subjects are concentrated in occipital, temporal and parietal areas (Cao et al., 2008). Specifically, the non-supervised pattern recognition algorithm, the support vector machine (SVM), has been applied in this study as a tool to identify athletes who suffer from residual functional deficits.

It should be noted that most subjects report concussion injury following impact to the side of their head. A recent report by Delaney et al. (2006) has also indicated that temporal impact of the head or helmet frequently results in a mechanism producing an MTBI. Biomechanical events set up by the concussive blow (such as amount of head movement about the axis of the neck at the time of impact, the site of impact, etc.) ultimately result in concussion (Shaw, 2002), and their analysis may contribute to a more accurate assessment of the degree of damage and potential for recovery.

Differential recovery of brain functions after first versus second MTBI as revealed by EEG-IQ values was clearly shown in this report. It is important to note, unlike the cases with a single concussion, that no obvious changes in EEG-IQ were observed within 21 days after second MTBI. These new findings are complementary to our previous observation of subjects with recurrent concussions. Specifically, the rate of recovery of “visual-kinesthetic integration” during dynamic postural tasks was significantly slower after the second concussion episode. Most importantly, unlike the first concussion, the presence of “visual-kinesthetic disintegration” was evident far beyond 10 days post-second concussion (Slobounov et al.,

2007). Collectively, our data support the hypothesis that a history of previous concussions may be associated with slower recovery of neurological function (Guskiewicz et al., 2003).

Our current EEG-IQ findings may shed additional light to the ongoing debate in the literature regarding the issue of cumulative effects of concussion. Sporadic evidence and clinical observations suggest that athletes with a history of previous concussions are more likely to have future concussive injuries (Guskiewicz et al., 2003). Recurrent brain injuries are likely to lead to cumulative neurological and cognitive deficits (Cantu, 2006). In fact, the cumulative effect in athletes experiencing three or more concussions was documented by the computerized NS test battery ImPact (Iverson et al., (2004). It should be noted, however, that the cumulative effect of one or two previous concussions was undetected using NS methodology (Iverson et al., 2006). While direct evidence for the “cumulative effect” hypothesis has not been provided, the patterns of results from our recent studies are consistent with the position that each concussion may potentially cause cumulative brain damage that can be detected using advanced electrophysiological measures of brain function (Gaetz et al., 2000).

In conclusion, the major findings from this study provide further evidence that residual brain dysfunction in concussed individuals may be detected in “asymptomatic” subjects via EEG-IQ measures. The current findings further reveal that alteration of brain functions as a result of MTBI may not be detected using conventional assessment tools. Whether this alteration is relatively transient resulting in reallocation of neural processing resources during increased processing load (McAllister et al., 2001), or a long-term persistent residual brain dysfunction, is yet to be determined.

The clinical implication of our current findings is that the athletes who prematurely return to play based solely on conventional symptoms resolution criteria within 10 days post-injury may be highly susceptible to future and more severe brain injuries (Cantu, 2006). Therefore, a combination of various assessment methods and techniques should be utilized in a clinical practice in order to make more accurate decision in terms of return-to-play and to indentify athletes at high risk for recurrent concussions (Notebaert and Guskiewicz, 2005). Symptoms resolution does not equal injury resolution. Additional research is needed to further validate and elaborate on the true clinical meaning of EEG-IQ measures in concussed individuals.

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Fig.1.

The n -level filter bank, at each level, the input is decomposed into high frequency component $h[n]$ and low frequency component $g[n]$. $g[n]$ is then down sampled by 2 and served as the input of the upper level decomposition, $h[n]$ is down sampled by 2 and served as the output of current level, i.e. detailed coefficients of the current level. Thus, the coefficients of the n -level DWT are composed of the detail coefficients of all of the n levels subspace and the approximation coefficients of the level n subspace, denoted as: $DWT_n(x) [d_1, d_2 \dots d_n, a_n]$

Fig.2.
Group mean values of neuropsychological test “Trails B” dynamics as a function of testing date and MTBI (1st versus 2nd concussion).

(a)

(b)

Fig.3.

Mean absolute values ($n=21$) of EEG-IQ at occipital, parietal and temporal ROIs prior to MTBI obtained during baseline testing and those on day 7, 14 and 21 post-first MTBI (a); and post-second MTBI (b).

Fig.4. Linear Pearson correlation between each subject's time period separating two concussive episodes (days) and EEG-IQ differences (i.e., % change of EEG-IQ values between baseline and 2nd concussion)

The mean values and standard deviation of the EEG-IQ at 5 ROIs under study prior to MTBI obtained during baseline testing and those in the same subjects after 1st and 2nd concussive episodes.

Table 1

Events/ROI	Frontal EEG-IQ (bit)	Central EEG-IQ (bit)	Temporal EEG-IQ (bit)	Parietal EEG-IQ (bit)	Occipital EEG-IQ (bit)
Baseline	1.87(0.21)	2.10(0.18)	2.23(0.18)	2.43(0.11)	2.63(0.19)
1 st MTBI	1.85(0.19)	2.05(0.20)	1.89(0.09)	2.01(0.10)	2.22(0.10)
2 nd MTBI	1.84(0.13)	2.01(0.11)	1.63(0.12)	1.82(0.13)	1.94(0.10)