

EFFECT OF CEREBRAL CONCUSSION ON THE COMPLEXITY OF CENTER OF PRESSURE TIME SERIES IN COLLEGIATE ATHLETES

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INTRODUCTION

Athletes with cerebral concussion, i.e., mild head injury (MHI), may be at increased risk for recurrent brain trauma, especially when returning to competition immediately after an initial injury (Guskiewicz et al., unpublished manuscript). Postural steadiness appears to be a reliable marker of recovery after cerebral concussion, with unsteadiness in athletes typically resolving within 3-5 days (Guskiewicz et al., 1996). Researchers have suggested, however, that the amount of center of pressure (COP) variability in subjects standing as still as possible may not reflect subtle postural control abnormality, and therefore, is inadequate for certifying that an athlete is free of impairment. (Guskiewicz et al., 1997).

An alternative approach for discriminating between healthy and brain-injured states is to measure the effect of injury on COP time series complexity. Approximate Entropy (ApEn) is a complexity measure that quantifies the ensemble amount of randomness in a time series (Pincus, 1991). ApEn measures the logarithmic probability that a series of points a certain distance apart will exhibit similar relative characteristics on the next incremental comparison (Harbourne & Stergiou, in press). ApEn generates values from 0-2, with higher values indicating greater complexity. Our purpose was to examine the effect of cerebral concussion on COP complexity in collegiate athletes.

METHODS

We analyzed a convenient sample of 5 male and 3 female collegiate athletes, 17-24 years old, with unsteadiness after cerebral concussion. Subjects had no other medical pathology. Postural steadiness was measured during pre-season, within 24 hours post injury, and every other day thereafter until steadiness returned to pre-season levels. For comparison, we analyzed data from 8 non-athlete control subjects, matched by age and gender, who were tested on 3 occasions.

Postural steadiness was evaluated using the Smart Balance Master System 8.0 (NeuroCom International, Inc., Clackamas, OR, USA), which measured vertical ground reaction forces at 100 Hz using dual force plates. COP location was estimated during 20-second trials. An equilibrium score was generated based on the average peak-to-peak amplitude of COP excursion measured during 6 sensory conditions. Athletes had greater than 5% decline in equilibrium score at 24 hours after injury. Many athletes also had complaints of headache, fatigue, dizziness, confusion, and / or blurred vision.

ApEn ($m=2$, $r = .2 \times \text{process s.d.}$, $N = 2000$) was calculated on the A/P and M/L components of COP time series data from two visual conditions (fixed platform, eyes open and eyes closed). Athlete data were analyzed from pre-season (Day 1), 24 hours post injury (Day 2), and from the day on which equilibrium scores returned to

preseason levels (Day 3). A mixed model (Group x Day) ANOVA was used for data analysis ($\alpha = .05$).

RESULTS AND DISCUSSION

On Day 1, athlete and non-athlete subjects displayed similar ApEn values for all time series (Figs. 1 & 2). On Day 2, athletes with MHI displayed a marked decline in time series complexity in both visual conditions. Even after steadiness returned to preseason levels (Day 3), ApEn values for injured athletes remained depressed.

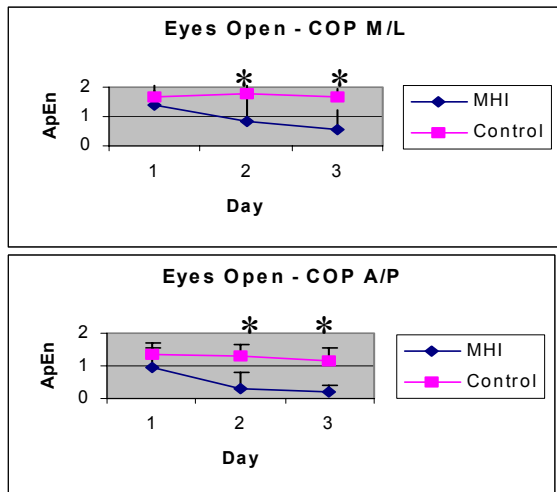


Figure 1: ApEn values for M/L and A/P COP time series in MHI and Control subjects standing with eyes open. * Between group comparison $p < .05$.

The data supported the hypothesis that pathology produces a loss of physiologic complexity (Lipsitz & Goldberger, 1992). More importantly, ApEn revealed postural control system disturbance that persisted despite the return of pre-injury steadiness, as measured by the amount of COP variability. Given the risk of recurrent concussion associated with returning to play before complete recovery, the failure of athletes with MHI to recover pre-injury levels of postural control system complexity might predispose them to further injury.

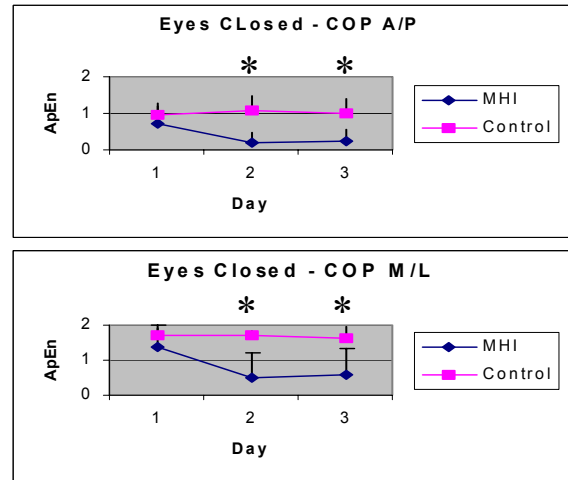


Figure 2: ApEn values for M/L and A/P COP time series in MHI and Control subjects with eyes closed. *Between group comparison $p < .05$.

SUMMARY

In contrast to measures of the amount of COP variability, ApEn may reveal subtle postural control system change resulting from MHI. ApEn shows promise as a valuable post-concussion assessment tool.

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