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Using neural signals to investigate athlete burnout

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Abstract

Objective: In the present study, we examined the relationships between athlete burnout, brain function, and self-assessment of performance, and how these relationships can be quantified using mobile electroencephalography (mEEG). Specifically, we performed this study to determine whether mEEG can be utilized as an objective measure of athlete burnout. In addition, we sought to determine whether there was any relationship between athlete burnout and athlete self-assessment of performance while controlling for our neural results.

Methods: We tested these relationships in a sample of high-performance athletes – whereby we had athletes complete an mEEG assessment and also had the athletes complete a questionnaire assessing burnout prior to participating in practice. Following practice, athletes were asked to provide a self-assessment of their performance.

Results: We found that athlete burnout had a moderate, negative relationship with neural oscillations associated with concentration. We also found that athletes with higher self-reported focus had larger neural oscillations associated with focus. Further, we also found that higher athlete confidence was associated with lower frontal neural oscillations.

Conclusions: Taken together, our findings suggest that athlete burnout has a negative impact on brain function, which may, in turn, affect sports performance.

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Keywords

Electroencephalography (EEG), Athletes, Burnout, Mobile EEG

Introduction

In recent years, it has become clear that cognitive exhaustion caused by repeated exposure to a stressor has a negative impact on performance, a phenomenon termed "burnout" (Perlman & Hartman, 2016). Importantly, there is evidence of burnout attenuating cognitive processes such as executive function, attention, and memory (see Deligkaris et al., 2014 for a review). Burnout in athletes is also associated with reduced athletic performance, increased sport drop-out (e.g., Gustafsson et al., 2017), and negative mental health outcomes (see Dubuc-Charbonneau & Durand-Bush, 2015 for a review). These findings highlight a need for further research into how burnout impacts athletes and how burnout might modulate direct measures of brain function. As sports performance is tied to neural regions of the brain responsible for motor control, optimal brain function is essential for successful motor outcomes. Thus, further insight into how burnout impacts athlete brain function is important to examine.

Electroencephalography (EEG), and especially mobile EEG (mEEG) is an excellent tool for measuring brain activity and understanding athlete burnout for several reasons. First, mEEG has already been validated in terms of comparing results with large array "research" EEG systems (Krigolson et al., 2017). Moreover, mEEG has been shown as a means for measuring cognitive fatigue across varied, real-world testing sites (n = 1000; Krigolson et al., 2021). These two findings suggest that mEEG can provide a valid measure of cognition in settings where previously EEG collection might not have been possible, such as before sports practice (see below, Pluta et al., 2018). Second, prior work has shown the usefulness of EEG in investigating relationships between brain function and athletic performance (e.g., Babiloni et al., 2008). Further research has used mEEG to investigate sports performance in baseball players, with athletes with lower pre-performance beta oscillations (EEG oscillations between 13 and 30 Hz) correlating with higher metrics of batting performance (Pluta et al., 2018). Third, there is evidence that EEG can provide a measure of burnout, as workers who were classified as "burnt-out" exhibited reduced alpha oscillations (EEG oscillations between 8 and 12 Hz) – suggesting a link between attentional processes associated with alpha oscillations and burnout levels (e.g., Golonka et al., 2019).

Here we sought to investigate the relationships between athlete burnout, brain function, and athlete self-assessments of performance. We collected resting-state mEEG data prior to sports practice as a measure of pre-task brain function free from arousal (Barry et al., 2007). We examined four different frequency bands of EEG activity: delta oscillations (1 to 3 Hz: motivation – Knyazev, 2012), theta oscillations (4 to 7 Hz: concentration – Cavanagh & Frank, 2014), alpha oscillations (8 to 12 Hz: attention – Klimesch, 2012), and beta oscillations (13 to 30 Hz: performance monitoring – Engel & Fries, 2010). Our goal was to determine whether athlete burnout impacted brain function as evidenced by relationships with the aforementioned EEG oscillations. Given the small number of prior investigations using EEG to investigate athlete burnout, our primary apriori hypothesis was that burnout would reduce frontal EEG oscillations (theta power: Golonka et al., 2008). As a secondary goal, we also investigated whether there were any relationships between athlete self-assessment of performance during practice (athlete confidence and focus) and EEG oscillations. We investigated athlete self-assessment of performance to explore how burnout-related changes to EEG oscillations might impact athlete performance. Thus, the present work uses mEEG as an objective method to examine the relationship between athlete burnout and brain function. Furthermore, we hoped to determine whether there was a relationship between self-assessment of performance and EEG oscillations to provide evidence for the use of mEEG as a tool for athletes and coaches to monitor brain function.

Methods

Participants

We tested 52 amateur athletes (42 male, 10 female) prior to practice, collected from a sports training center (Victoria, B.C., Canada). Due to a collection oversight, the ages of participants were not recorded – however, all were university-age athletes. Our sample consisted of 47 baseball players, three basketball players, one weightlifter, and one rugby player. Given the small sample sizes of some of the athlete categories, we collapsed across all athlete groups for the analysis. Prior to data collection, athletes provided written, informed consent. The University of Victoria Human Research Ethics Board approved all experimental procedures (Ethics Protocol Number: 16-428).

Materials and Procedures

Pre-practice evaluations

Prior to practicing for their respective sport, athletes were given the Athlete Burnout Questionnaire (ABQ), which consists of 15 questions that assess athlete burnout (Raedeke & Smith, 2001). For each question, athletes ranked themselves on a scale from 1 (almost never) to 5 (almost always). Higher scores indicate greater levels of burnout, with the lowest possible score being 15 (no burnout) and the highest possible score being 75 (high levels of burnout).

EEG data collection

Following the completion of the ABQ, resting-state EEG data were collected from each athlete prior to practice. The EEG system utilized for data collection is a dry-electrode mobile Cognionics EEG system (Marini et al., 2019), a mobile system that uses two frontal channels (AF7 and AF8) and two posterior channels (TP9 and TP10) in addition to a reference channel and a ground channel. Both the reference and the ground were placed in the middle of each subject's forehead, with the ground placed above the eyebrows and the reference placed above the ground. EEG data were recorded for two minutes with the athlete's eyes open, followed by two minutes of eyes-closed EEG data. Participants were instructed to avoid blinking as much as possible. In the present work, we restricted our analysis to the eyes-open EEG data only given the potential bias of enhanced EEG alpha oscillations when someone's eyes are closed.

Post-practice evaluation

Following practice, athletes were then given a second questionnaire which asked how they had performed during practice. For each question, athletes were asked to rank themselves on a scale of 1 to 5, with 1 being "Very Weak" and 5 being "Very Strong'. Of the post-practice questions, two were shown to have significant correlations with the EEG data: "How focused did you feel today?" and "How confident did you feel today?".

Data Preprocessing

EEG data were pre-processed in MATLAB using custom-written scripts adapted from EEGLAB (Delorme & Makeig, 2004). Data were sampled at 500 Hz using a Bluetooth connection between the Cognionics device and an Apple iPad running the PEER app (Brain

Wave Software, Victoria, BC). Pre-processing of the EEG involved the application of a Butterworth filter with a high-pass parameter of 1 Hz and a low-pass parameter of 30 Hz, alongside a 60 Hz notch filter. The EEG data were then segmented into 1000 ms epochs, with 900 ms of overlap. An automatic artifact rejection algorithm was performed on each epoch of EEG data using a difference of 100 μV, and any segments containing artifacts were removed (Luck, 2014). The two frontal channels (AF7, AF8) were pooled together, and the two posterior channels (TP9, TP10) were also pooled as we did not anticipate any differences in lateralized brain activity. Any channel with greater than 30% of its data affected by artifacts prior to pooling was removed entirely. A Fast-Fourier Transformation was then conducted on each epoch of the EEG data to extract frequencies between 1 and 30 Hz for each participant. Following this, we computed the average spectral power for each frequency band of interest: delta (1 to 3 Hz), theta (4 to 7 Hz), alpha (8 to 12 Hz), and beta (13 to 30 Hz) for each participant.

Data Analysis

We sought to investigate the relationship between athlete brain function, burnout, and performance. We calculated Pearson correlations between EEG data and ABQ scores. As the post-practice responses were ordinal variables, we instead calculated Spearman correlations between EEG data and those responses. Data were tested for normality, and non-normal data were corrected using a logarithmic transformation. For outlier removal (set *a-priori*), we visualized Cook's distance for each correlation and any participant that had multiple (n > 2) EEG values with a Cook's distance greater than $\frac{4}{52}$ were removed. Boxplots were used to confirm the Cook's distance findings. Using this outlier approach, we removed two participants, giving a final sample of 50 participants. All statistical analyses were conducted in R (version 4.2.0, R Team), we used $\alpha = .05$ and calculated mean and 95% confidence intervals for survey responses.

Results

The average score on the ABQ was 26.3 (95% CI [24.3, 28.3], Range: 14.0, 42.0). In terms of athlete confidence, the average score was 3.4 (95% CI [3.2, 3.4], Range: 1.0 ,5.0). In terms of athlete focus, the average score was 3.6 (95% CI [3.3, 3.8], Range: 1.0, 5.0).

Importantly, we found that athlete burnout was negatively correlated with frontal EEG bands. For frontal EEG amplitudes, we found that delta amplitude (r(48) = -.33, p = .02), theta amplitude (r(48) = -.42, p = .002) and beta amplitude (r(48) = -.30, p = .03) were all moderately, negatively correlated with ABQ scores. These correlations thus show a negative relationship between higher levels of athlete burnout and brain function.

When examining the athletes' self-assessment responses, we found that athlete focus scores were positively correlated with posterior theta amplitude (r(48) = .31, p = .03) and posterior alpha amplitude (r(48) = .33, p = .01). In contrast, self-reported athlete confidence was found to have a negative correlation with frontal theta amplitude (r(48) = -.30, p = .04).

Discussion

Our findings provide novel evidence that athlete burnout is related to changes in brain function. Importantly, our work demonstrates for the first time the utility of using mEEG to investigate burnout in more varied research environments, specifically in athletes. Athletes with higher burnout scores had reduced cognitive control, evidenced by reductions in beta and theta oscillations (Cavanagh & Frank, 2014; Engel & Fries, 2010). Further, burnt-out athletes exhibited decreased motivation (reduced delta oscillations; Knyazev, 2012). These results are in line with previous work examining detriments to executive function caused by job burnout and extend these findings to athletes (Deligkaris et al., 2014). Of particular interest is how burnout-related changes in brain function may also bring about detriments in sports performance. For example, decreased theta oscillations are associated with reduced basketball free-throw performance (Chuang et al., 2013).

To investigate the relationship between EEG oscillations and performance, we examined how EEG power was related to self-assessments of performance. We found that parietal theta oscillations were positively related to focus, extending prior work showing that parietal theta oscillations reflect the coupling of attentional networks tied to cognitive control (Sauseng et al., 2008). In addition, given the close links between parietal and frontal theta oscillations, these findings indicate a possible mechanism through which athlete burnout might reduce theta oscillations and thereby impact athlete performance – although we stress that future research is needed to prove this assertion. Parietal alpha oscillations were also positively related to focus, in-line with results showing greater parietal alpha power during tasks requiring focused attention (Benedek et al., 2014). However, the amplitude of frontal theta oscillations was negatively correlated with confidence, suggesting greater confidence is associated with worse cognitive control. Interestingly, higher confidence has been shown to be associated with less burnout (Kjørmo & Halvard, 2002), and thus our result could suggest that the relationship between cognitive control, confidence, and athlete burnout may not be linear but instead more complex. Nonetheless, our results provide evidence of the relationships between athlete brain function and resulting performance and highlight one possible mechanism for how athlete burnout changes performance.

References

[1]. Perlman, B., & Hartman, E. A. (2016). Burnout: Summary and Future Research. *Hum Relat*, *35*(4), 283–305. https://doi.org/10.1177/001872678203500402

[2]. Deligkaris, P., Panagopoulou, E., Montgomery, A. J., & Mansoura, E. (2014). Job burnout and cognitive functioning: A systematic review. *Work Stress*, *28*(2), 107–123. https://doi.org/10.1080/02678373.2014.909545

[3]. Gustafsson, H., DeFreese, J. D., & Madigan, D. J. (2017). Athlete burnout: review and recommendations. *Curr Opin Psychol*, *16*, 109–113. https://doi.org/10.1016/J.COPSYC.2017.05.002

[4]. Dubuc-Charbonneau, N., & Durand-Bush, N. (2015). Moving to action: The effects of a self-regulation intervention on the stress, burnout, well-being, and self-regulation capacity levels of university student-athletes. *J Clin Sport Psychol*, *9*(2), 173–192. https://doi.org/10.1123/JCSP.2014-0036

[5]. Krigolson, O. E., Williams, C. C., Norton, A., Hassall, C. D., & Colino, F. L. (2017). Choosing MUSE: Validation of a low-cost, portable EEG system for ERP research. *Front Neurosci*, *11*(MAR), 109. https://doi.org/10.3389/FNINS.2017.00109/BIBTEX

[6]. Krigolson, O. E., Hammerstrom, M. R., Abimbola, W., Trska, R., Wright, B. W., Hecker, K. G., & Binsted, G. (2021). Using Muse: Rapid Mobile Assessment of Brain Performance. *Front Neurosci*, *15*, 56. https://doi.org/10.3389/FNINS.2021.634147/BIBTEX

[7]. Babiloni, C., del Percio, C., Iacoboni, M., Infarinato, F., Lizio, R., Marzano, N., Crespi, G., Dassù, F., Pirritano, M., Gallamini, M., & Eusebi, F. (2008). Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms. *J Physiol*, *586*(1), 131–139. https://doi.org/10.1113/JPHYSIOL.2007.141630

[8]. Pluta, A., Williams, C. C., Binsted, G., Hecker, K. G., & Krigolson, O. E. (2018). Chasing the zone: Reduced beta power predicts baseball batting performance. *Neurosci Lett*, *686*, 150–154. https://doi.org/10.1016/j.neulet.2018.09.004

[9]. Golonka, K., Gawlowska, M., Mojsa-Kaja, J., Marek, T., & Topa, G. (2019). Psychophysiological Characteristics of Burnout Syndrome: Resting-State EEG Analysis. *Biomed Res Int*, *2019*. https://doi.org/10.1155/2019/3764354

[10]. Barry, R. J., Clarke, A. R., Johnstone, S. J., Magee, C. A., & Rushby, J. A. (2007). EEG differences between eyes-closed and eyes-open resting conditions. *Clin Neurophysiol*, *118*(12), 2765–2773. https://doi.org/10.1016/J.CLINPH.2007.07.028

[11]. Knyazev, G. G. (2012). EEG delta oscillations as a correlate of basic homeostatic and motivational processes. *Neurosci Biobehav Rev*, *36*(1), 677–695. https://doi.org/10.1016/J.NEUBIOREV.2011.10.002

[12]. Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. *Trends Cogn Sci*, *18*(8), 414–421. https://doi.org/10.1016/J.TICS.2014.04.012

[13]. Klimesch, W. (2012). Alpha-band oscillations, attention, and controlled access to stored information. *Trends Cogn Sci*, *16*(12), 606–617. https://doi.org/10.1016/j.tics.2012.10.007

[14]. Engel, A. K., & Fries, P. (2010). Beta-band oscillations--signalling the status quo? *Curr Opin Neurobiol*, *20*(2), 156–165. https://doi.org/10.1016/J.CONB.2010.02.015

[15]. Raedeke, T. D., & Smith, A. L. (2001). Development and Preliminary Validation of an Athlete Burnout Measure. *J Sport Exerc Psychol*, *23*(4), 281–306. https://doi.org/10.1123/JSEP.23.4.281

[16]. Marini, F., Lee, C., Wagner, J., Makeig, S., & Gola, M. (2019). A comparative evaluation of signal quality between a research-grade and a wireless dry-electrode mobile EEG system. *J Neural Eng*, *16*(5), 054001. https://doi.org/10.1088/1741-2552/AB21F2

[17]. Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J Neurosci Methods*, *134*(1), 9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009

[18]. Luck, S. (2014). *An Introduction to the Event-Related Potential Technique*. *MIT Press*.

[19]. Chuang, L. Y., Huang, C. J., & Hung, T. M. (2013). The differences in frontal midline theta power between successful and unsuccessful basketball free throws of elite basketball players. *Int J Psychophysiol*, *90*(3), 321–328. https://doi.org/10.1016/J.IJPSYCHO.2013.10.002

[20]. Sauseng, P., Klimesch, W., Gruber, W. R., & Birbaumer, N. (2008). Cross-frequency phase synchronization: a brain mechanism of memory matching and attention. *NeuroImage*, *40*(1), 308–317. https://doi.org/10.1016/J.NEUROIMAGE.2007.11.032

[21]. Benedek, M., Schickel, R. J., Jauk, E., Fink, A., & Neubauer, A. C. (2014). Alpha power increases in the right parietal cortex reflects focused internal attention. *Neuropsychologia*, *56*(100), 393–400. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2014.02.010

[22]. Kjørmo, O., & Halvari, H. (2002). Relation of burnout with lack of time for being with significant others, role conflict, cohesion, and self-confidence among Norwegian Olympic athletes. *Percept Mot Skills*, *94*(3 Pt 1), 795–804. https://doi.org/10.2466/PMS.2002.94.3.795

Figures

Figure 1. (A) Athlete burnout scores and FFT power & (B) Self-assessment scores and FFT power. Note: ***** = significant at .05, ****** = significant at .01.