Athletes in a Slump: Neurophysiological Evidence from Frontal Theta Activity

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ABSTRACT

The purpose of this study was to investigate the neurophysiological differences in athletes who suffer from a slump and other athletes who do not. Eighteen high school student athletes participated in this experiment. A subjective questionnaire was conducted to identify athletes in a slump (i.e., the slump group) and not in a slump (i.e., the non-slumped group). EEG data was recorded at 4 regions (left prefrontal, right prefrontal, left frontal, and right frontal). A two-way (2 groups x 4 regions) ANOVA was performed on the dependent variable (i.e., frontal theta power). The findings of this study demonstrated that participants in the non-slumped group showed higher frontal theta activity than their counterparts in the slumped group. From the findings of this study, it is suggested that mental fatigue may cause low frontal theta activity in athletes who experience a slump. The present study makes an important contribution to the current literature by being the first to report that EEG theta power over frontal regions can be used as a marker of athletes suffering from a slump.

1. Introduction

Sports slump is a well-known phenomenon in competitive sports. In this event, athletes experience an unexpected, prolonged decrease in their performance. In many cases, athletes remain unsuccessful in sustaining or restoring peak performance, despite investment of full physical and psychological efforts. The underlying mechanisms, causes, and consequences associated with sports slump are elusive, poorly defined, and largely controversial among researchers possibly due to the complex nature of this phenomenon. Recently, Ball (2013) demonstrated that sports slump may have some connections with internal psychological characteristic of athletes. In order to explain athletic performance slump, Goldberg (1998) highlighted that the state of slump is generated primarily from athletes' cognitive and negative affective states in response to poor performance.

Specifically, the appearance of several negative psychological conditions including de-motivation, decreased levels of confidence, distractions, heightened level of anxiety, and emotional disturbance are found to be correlated with a sports slump (Horn, 1984; Taylor, 1988). Moreover, it has been believed that the state of slump seems to be associated more closely with psychological factors (Isoard-Gautheur, Oger, Guillet, and Martin-Krumm (2010); Raedeke and Smith (2001). Recently, neurophysiological approaches documented that the performance of athletes is linked with some neural mechanisms. For example Kim, Lee, Kim, Park, Kim, Moon, Woo, & Tennant (2008) indicated that sports performance is largely correlated with the efficiency of neural networks underlying certain motor skills. Therefore, it seems logical that the state of slump can be explained more accurately and precisely by utilizing neurophysiological methods such as electroencephalogram (EEG).

To date, there is no neurophysiological hypothesis that helps to explain a slump of athletes. However, there is some evidence indicating that the phenomenon of slump shares several characteristics with individuals experiencing burnout, depression, and mental fatigue (Purvis, Gonsalves, & Deuster, 2010). Deficits in cognition and attention have repeatedly been reported in these conditions (Hammar & Årdal, 2009) that may differently affect brain activity measured through theta power (Tanaka, Shigihara, Ishii, Funakura, Kanai, & Watanabe, 2012; van Luijtelaar, Verbraak, van den Bunt, Keijsers,& Arns, 2010). For example, El-Badri, Ashton, Moore, Marsh, & Ferrier, (2001) found increased theta power in patients with depression compared with healthy controls.

Frontal theta has been shown to reflect processes of cognitive control and attention during execution of the tasks requiring conflict monitoring (Cohen, &Donner, 2013). In addition, Wascher, Rasch, Sänger, Hoffmanna, Schneider, Rinkenauera,

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Heuera, & Gutberlet (2014) demonstrated that frontal theta can be a reliable marker of distinct changes in cognitive processing associated with increased mental fatigue. Tanaka et al. (2012) also demonstrated that a low level of theta power was connected with mental fatigue.

It is well known that the major symptoms of a slump experienced by athletes include mental fatigue and depression. Thus, it is believed that measuring frontal theta activity may provide useful information in understanding athletes who suffer from a slump. Therefore, the purpose of this study was to determine the differences in neurophysiological functions measured through the frontal theta activity in athletes in a slump (i.e., the slump group) and those not in a slump (i.e., the no-slump group). It is hypothesized that the slump group, compared with the no-slump group, may show decreased theta power, based on the previous findings that conditions of depression (El-Badri et al, 2001) and mental fatigue (Tanaka et al., 2012) exhibited a significantly low level of theta power.

2. Methods

2.1 Participants

Eighteen high school student athletes (male = 13, female = 5) whose ages ranged from 17 to 18 years (mean age = 17.7) years participated in this experiment. A subjective questionnaire was administered to identify athletes in a slump and not in a slump. Based on the results of the questionnaire, participants were divided into one of two experimental groups: (1) the slumped group and (2) the non-slumped group. The classification of participation into the slumped and non-slumped groups was based on participant's subjective responses indicating their current level of slump. A subjective questionnaire was used because there is no existing appropriate inventory measuring slump. All participants were right-handed. They were non-smokers and had not been diagnosed with any past neurological or psychiatric problems. All participants gave informed consent, approved by our Institutional Review Board.

2.2 EEG and Task

This study utilized WEEG-8 channel (Model: LXE5208-RF, Laxtha Inc. Korea), and the measurement was recorded according to the System of Electrode Placement (Jasper, 1958) at 4 sites that are related to stress response (Fp1: left prefrontal, Fp2: right prefrontal, F3: left frontal, F4: right frontal). The reference electrode was the right earlobe and the grounding electrode was placed at a prefrontal central electrode (Fpz). Measurements were taken to ensure that the scalp resistance at each measurement location was below 5KΩ before official measurements began. The EEG sampling rate was set at 256Hz, and a band pass filter of 0.1-100Hz was deployed while the EEG signal was being entered. Telescan 2.9 (Laxtha Inc.) software was used for the EEG analysis. EEG signals, including EOGs, with a value exceeding $\pm$100μV were excluded from the EEG analysis. After filtering signals of 1-30Hz with a FIR band pass filter, the resulting EEG signal was epoched at one-second intervals. The Power Spectral Densities (PSD) of the theta (4-7Hz) frequency ranges were calculated in epoch using Fast Fourier Transform (FFT).

2.3 Procedure

Upon arriving at the testing room, participants were briefed on the main objectives of the experiment. During EEG recording, participants were asked to remove all the metallic objects (i.e., rings, keys, cell phones, coins, and necklaces) that might influence EEG signals. Each participant was placed in a comfortable chair, with the electrode cap in place, and gel was applied at the 4 electrode positions. EEG Gel (Electro-gel™, Electro-Cap International Inc., Eaton, OH) was applied into each electrode to connect with the surface of the scalp in order to drop the electric resistance of the scalp below 5kΩ. Each participant was requested to refrain from any bodily movements including eye blinking and the swallowing of saliva which could contaminate EEG signals. Once the EEG signals were stabilized, the brain waves were recorded in a resting state while the participant was asked to look at a fixed cross displayed in the center of a computer monitor for a three-minute duration. The total recording time for each participant was approximately 10 minutes.

2.4 Experimental Design and Analysis

To determine the effects of slump on frontal theta activity, a two-way (2 groups x 4 regions) was conducted on the dependent variable (i.e., frontal theta power). The level of statistical significance was at α = .05, and Tukey's HSD was used for post-experimental verification. All statistical analysis was performed by using SPSS 17.

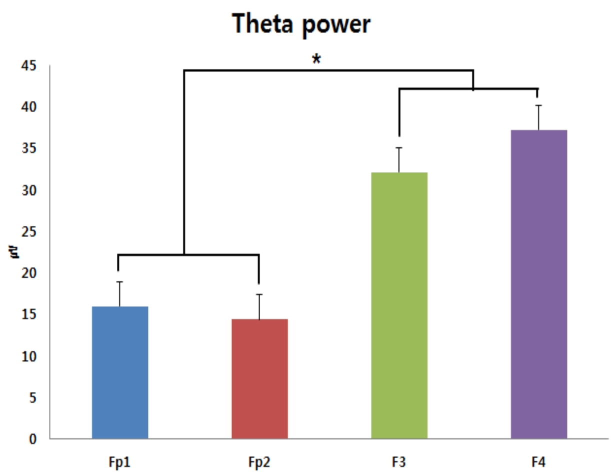
3. Results

The analysis of theta power showed the significant main effects of groups, $F\,(1, 64) = 26.540$, $p < .05$, $\eta^2 = .293$ and regions, $F\,(3, 64) = 14.920$, $p < .05$, $\eta^2 = .412$ (Figure 1). No statistically significant interaction between groups and regions were found. These results indicate that participants in the non-slumped group showed higher frontal theta activity than those in the slumped group. A follow-up analysis using Tukey's HSD indicated that the theta activities of F3 and F4 electrodes were significantly higher than those of Fp1 and Fp2 (Figure 2).

Figure1. Frontal theta power difference between slumped and non-slumped groups

* p< .05

Figure2. Frontal theta power differences among Fp1, Fp2, F3 and F4



* p< .05

4. Discussion

This study investigated the neurophysiological differences in athletes who are in a slump and others who are not. The results showed significantly higher frontal theta power in the non-slumped group compared with the slumped group. In other words, significantly low frontal theta power in the slumped group during a task requiring attention indicates that these participants may experience deficits in attention. By contrast, higher frontal theta power in the non-slumped group indicates superior concentration.

These differences in frontal theta activity are possibly associated with the fact that athletes in a slump are characterized by certain negative psychological states such as the loss of concentration, increased stress and anxiety, and frustration. It has been suggested that frontal theta activity is negatively correlated with levels of anxiety, mental stress (Suetsug, Mizuki, Ushijima, Kobayashi, Tsuchiya, Aoki, & Watanabe, 2000), arousal (Kubota, Sato, Toichi, Murai, Okada, Hayashi, & Sengoku, 2001) and positively related to concentration (Kubota, et al., 2001; Laukka, Järvilehto, Alexandrov, & Lindqvist, 1995), attention (Missonnier, Deiber, Gold, Millet, Pun, Fazio-Costa, & Ibáñez, 2006), and positive emotional states (Aftanas, & Golocheikine, 2001). In addition, pervious research corroborated that participants with cognitive impairments, relative to healthy controls, exhibited a reduction in theta activity while performing tasks requiring cognitive control functions (Cummins and Finnigan, 2007). It has also been demonstrated that theta activity in frontal brain regions increased as the learning level of participants increased with practice during the execution of tasks (Laukka, et al., 1995; Smith, McEvoy, & Gevins, 1999). Research indicated that when a skill improves as a result of practice, participants tend to perform the same task with a lesser investment of cognitive effort and with feelings of ease, state of relaxation, and confidence (Ericsson, 2003; Law, Côté, & Ericsson, 2008). These findings tend to suggest that the slumped group relative to the non-slumped group may be inferior in attention control capacity possibly due to underlying mechanisms associated with negative psychological states. It can be suggested that participants in the slumped group might have performed the task under more psychological stress and anxiety and with less concentration.

Another explanation of this finding is that the mental fatigue of athletes experiencing a slump may possibly have resulted in low amplitude of theta activity. Previously it was indicated that mental fatigue had an influence on the amplitude of theta rhythms over frontal scalp sites (Wascher et al, 2014). On the other hand, Craig, Tran, Wijesuriya and Nguyen (2012) reviewed fatigue related EEG studies and found an increase in theta activity, with no change found in the two studies. No studies found significant decreases in theta activity. However, the present study showed lower theta activity.

Our study indicated that theta activity decreases when a person experiences mental fatigue and stump. This finding suggests that EEG theta power over frontal regions can be used as a marker of athletes who are in a slump. Further studies are indeed necessary by using event-related potentials (ERPs), functional magnetic resonance imaging (fMRI), and magnetoencephalography (MEG) techniques in order to corroborate our findings.

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Reference

Aftanas, L. I., & Golocheikine, S. A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: high-resolution EEG investigation of meditation. *Neuroscience letters*, *310(1)*, 57-60.

Ball, C. T. (2013). Unexplained Sporting Slumps and Causal Attributions. *Journal of Sport Behavior, 36*(3), 233-242.

Cohen, M. X., & Donner, T. H. (2013). Midfrontal conflict-related theta-band power reflects neural oscillations that predict behavior.*Journal of neurophysiology, 110*(12), 2752-2763.

Craig, A., Tran, Y., Wijesuriya, N., & Nguyen, H. (2012). Regional brain wave activity changes associated with fatigue. *Psychophysiology, 49*(4), 574–582.

Cummins, T. D., & Finnigan, S. (2007). Theta power is reduced in healthy cognitive aging. *International Journal of Psychophysiology, 66*(1), 10-17.

Demakis, G. J. (2004). Frontal lobe damage and tests of executive processing: a meta-analysis of the category test, stroop test, and trail-making test. *Journal of Clinical and Experimental Neuropsychology*, *26*(3), 441-450.

El-Badri, S. M., Ashton, C. H., Moore, P. B., Marsh, V. R., & Ferrier, I. N. (2001). Electrophysiological and cognitive function in young euthymic patients with bipolar affective disorder. *Bipolar Disorders,3*(2),79-87.doi:10.1034/j.1399-5618.2001.030206.x

Ericsson, K. A. (Ed.). (2003). Expert performance in sports: Advances in research on sport expertise. *Human Kinetics*.

Goldberg, A. S. (1998). *Sports slump busting*: Human Kinetics.

Goodger, K., Gorely, T., Lavallee, D., & Harwood, C. (2007). Burnout in sport: A systematic review. *Sport Psychologist, 21*(2), 127-151.

Grove. (2004). Performance slumps in sports: Prevention and coping. *Encyclopedia of Applied Psychology, 2*, 833-841.

Hammar, Å., & Årdal, G. (2009). Cognitive functioning in major depression–a summary. *Frontiers in Human Neuroscience, 3*, 26, 1-10.

Horn, T. (1984). The expectancy process: Causes and consequences. In W. F. S. J. M. Williams (Ed.), *Cognitive Sport Psychology* (pp. 199-211). Lansing, NY: Sport Science Associates.

Isoard-Gautheur, S., Oger, M., Guillet, E., & Martin-Krumm, C. (2010). Validation of a French version of the Athlete Burnout Questionnaire (ABQ): In competitive sport and physical education context. *European Journal of Psychological Assessment, 26*(3), 203-211. doi: 10.1027/1015-5759/a000027

Kim, J., Lee, H., Kim, W., Park, H., Kim, S., Moon, D., Woo, M., & Tennant, L. K (2008). Neural correlates of pre-performance routines in expert and novice archers. *Neuroscience Letters*, 445 (3), 236–241.

Kubota, Y., Sato, W., Toichi, M., Murai, T., Okada, T., Hayashi, A., & Sengoku, A. (2001). Frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. *Cognitive Brain Research, 11(2)*, 281-287.

Laukka, S. J., Järvilehto, T., I. Alexandrov, Y., & Lindqvist, J. (1995). Frontal midline theta related to learning in a simulated driving task. *Biological Psychology, 40*(3), 313-320. doi: http://dx.doi.org/10.1016/0301-0511(95)05122-Q.

Law, M. P., Côté, J., & Ericsson, K. A. (2008). Characteristics of expert development in rhythmic gymnastics: A retrospective study. *International Journal of Sport and Exercise Psychology, 5*(1), 82-103.

Missonnier, P., Deiber, M. P., Gold, G., Millet, P., Pun, M. G. F., Fazio-Costa, L., Giannakopoulos, P.,& Ibáñez, V. (2006). Frontal theta event-related synchronization: comparison of directed attention and working memory load effects. *Journal of neural transmission, 113*(10), 1477-1486.

Purvis, D., Gonsalves, S., & Deuster, P. A. (2010). Physiological and psychological fatigue in extreme conditions: overtraining and elite athletes. *PM&R: the journal of injury, function, and rehabilitation, 2*(5), 442-450.

Raedeke, T. D., & Smith, A. L. (2001). Development and preliminary validation of an athlete burnout measure. *Journal of Sport & Exercise Psychology, 23*(4), 281-305.

Smith, M. E., McEvoy, L. K., & Gevins, A. (1999). Neurophysiological indices of strategy development and skill acquisition. *Cognitive Brain Research, 7*(3), 389-404.

Soo, C. K., Mee, Y. K., & Ah, M. L. (2004). The influence of plateau and slump on dance performance and adaptation to universtiy life of students majoring in dance. *Korean Journal of Physical Education, 43*(3), 571-580.

Suetsugi, M., Mizuki, Y., Ushijima, I., Kobayashi, T., Tsuchiya, K., Aoki, T., & Watanabe, Y. (2000). Appearance of frontal midline theta activity in patients with generalized anxiety disorder. *Neuropsychobiology, 41*(2), 108-112.

Tanaka, M., Shigihara, Y., Ishii, A., Funakura, M., Kanai, E., & Watanabe, Y. (2012). Effect of mental fatigue on the central nervous system: an electroencephalography study. *Behavioral and Brain Functions, 8*(1), 48-55.

Taylor, J. (1988). Slumpbusting: A systematic analysis of slumps in sports. *The Sport Psychologist, 2*(1), 39-48.

van Luijtelaar, G., Verbraak, M., van den Bunt, M., Keijsers, G., & Arns, M. (2010). EEG findings in burnout patients. *The Journal of Neuropsychiatry and Clinical Neurosciences, 22*(2), 208-217.

Wascher, E., Rasch, B., Sänger, J., Hoffmanna, S., Schneider, D., Rinkenauera, G., Heuera, H., &Gutberlet, I. (2014).Frontal theta activity reflects distinct aspects of mental fatigue. *Biological Psychology,* 96, 57-65.