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EEG FREQUENCIES PATTERN AS BRAIN SIGNATURE OF EMOTIONAL BURNOUT. ANXIETY TENSION STAGE FORMATION

Semen A. Mushta[1], Svitlana P. Palamar[2], Dmytro V. Harmatiuk[1], Anton O. Popov[1,5], Joao M. Alves Ferreira[3], Mykola Yu. Makarchuk[4], Sergii V. Tukaiev[4]

[1]Igor Sikorsky Kyiv Polytechnic Institute, Kyiv, Ukraine
[2]Borys Grinchenko Kyiv Metropolitan University, Kyiv, Ukraine
[3]Universidade de Coimbra, Coimbra, Portugal
[4]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
[5]Ukrainian Catholic University, Lviv, Ukraine

Abstract

Introduction. The prospect of increasing annually makes burnout a global phenomenon, one of the most common stress-related and mental disorders. Emotional burnout leads to serious destructive consequences for society, organizations, and interpersonal relationships due to mental and behavioural changes. Burnout develops gradually and often goes unnoticed, with symptoms that may take years to manifest and lead to significant mental and behavioral changes. Despite its impact, the processes underlying burnout remain largely unknown due to a lack of specialized studies identifying specific biomarkers. Early detection of burnout, particularly at the critical onset of symptoms, is essential.
Aim. This study aimed to examine EEG frequency changes associated with the severity of the Anxiety-Tension stage of Emotional Burnout.
Materials and methods. A total of 752 participants, including students and staff from Taras Shevchenko National University of Kyiv (209 males, mean age=19.2; 543 females, mean age=18.28), were assessed using the 84-item Boyko's Syndrome of Emotional Burnout Inventory. EEG data were recorded during a 3-minute resting state with eyes closed, and artifact-free segments from all frequency bands (0.2-45 Hz) were analyzed. Normalized power spectral densities (PSD) were calculated, focusing on the 61-70 second segment of the recordings.
Results. The results revealed burnout-related changes in spectral characteristics associated with the Anxiety-Tension stage, with significant alterations observed in the theta 2 band (frontal and left temporal-parietal cortex), alpha 2 band (right parietotemporal cortex), and beta 1 band (left frontal-central-right parietal axis).
Conclusions. These findings suggest that the Anxiety-Tension stage primarily impacts processes related to short-term memory and focused attention, providing a potential framework for the early identification of burnout through neurophysiological markers.

Keywords: **emotional burnout, anxiety tension, EEG, power spectral density**

INTRODUCTION

According to the most conservative estimates, 10% of the EU and 17% of the non-EU countries' workforce feels burned-out [1]. The prospect of increasing annually makes burnout a global phenomenon, one of the most common stress-related and mental disorders. Emotional burnout leads to serious destructive consequences for society, organizations, and interpersonal relationships due to mental and behavioural changes [2, 3, 4]. Clinical burnout/exhaustion disorder is associated with sleep impairments, cognitive impairments, and neurobiological changes [5]. The burnout features as a process are that it develops gradually, unnoticed by the person, and its symptoms may appear after several years [6, 7].

The burnout diagnosis is made based on the results of special tests (MBI mostly) and numerous studies consider emotional burnout as a psychological phenomenon [2, 3, 4, 8, 9]. Even though burnout has been studied for more than half a century as a separate syndrome, a clearly agreed definition is still not obvious [4, 8, 9] and strong, specific biomarkers for this condition are not detected or do not exist at all [5, 10]. Despite decades of research, the absence of reliable biomarkers for burnout hampers early intervention and personalized treatment strategies. Neurophysiological tools like EEG offer a unique opportunity to bridge this gap by providing non-invasive, cost-effective methods to monitor brain activity. EEG provides superior temporal resolution, enabling the detection of rapid neural processes associated with burnout, making it particularly suited for studies focusing on cognitive and emotional regulation. The processes underlying burnout are largely unknown due to the lack of specialized studies and methodological differences among these studies [11]. Lack of information about the changes that occur in the brain during the development of this stress-related disorder, other mental conditions, does not allow it to be accurately diagnosed in the early stages or effectively treated.

There are very few studies focusing on the neurophysiological aspects of emotional burnout. The identification of highly specific biomarkers of burnout is hindered by the limited comparability across studies and the heterogeneity of potential biomarkers [12]. The neurophysiological studies (fMRI, PET, EEG) allowed associating the severity of emotional burnout with changes in the brain functioning including local, topographic organization (the brain structures, cortex areas, morphological changes and functional state characteristics).

Available data from a set of studies on local changes allowed the identification of some critically important brain structures involved in the development of burnout – or more precisely, those that suffer from the negative impact of everyday stress and are responsible for characteristic symptoms. The primary stage of emotional burnout (emotional exhaustion) is associated with decreased activation of the structures involved in empathic behaviour (anterior insula and inferior frontal gyrus cluster (AI/IFG) and the temporoparietal junction (TPJ) [13]. Severity of emotional exhaustion is associated with the increased activity of the right posterior cingulate cortex and middle frontal gyrus [14]. Studies highlight that the posterior cingulate cortex (PCC) (Brodmann areas 23/31) plays a crucial role in complex forms of cognition (memory, navigation, and narrative comprehension) [15].

In burned-outpatients, a significant decrease in the volume of the anterior cingulate cortex (ACC), dorsolateral prefrontal cortex (dlPFC), and two structures of the striatum – the caudate nucleus and the putamen – was found [16]. The same changes in volume were detected in the caudate and putamen in stress-related mental fatigue [17]. This explains the effects on emotion regulation and motivational behaviours, as dopamine in the striatum is an important part of the brain reward system (BRS) [18]. Emotional exhaustion correlates with decreased gray matter volume in the bilateral ventromedial prefrontal cortex (vmPFC) and the left insula [19]. vmPFC and dlPFC are involved in depression development – the projections of the first to periaqueductal gray, hypothalamus, and amygdala explain the coordination of the physiological components of negative emotion. In addition to association with working memory, attentional control, and intention formation, dlPFC is also involved in the regulation of negative emotions by reappraisal/suppression strategies [20]. Reduced thickness of PFC because of chronic occupational stress is connected with the impairment of the ability to down-modulate negative emotions [21]. Alterations of brain states under chronic stress are broad, and may have opposing effects (e. g., dendritic complexity of granule cell layer of the dentate gyrus of the hippocampus). Hippocampal synchrony and gamma oscillations in the nucleus accumbens reflect the vulnerability to depression [22].

Logically, the observed changes will be reflected in the electrical activity of the brain recorded using EEG. In one of a pioneering study, Luijtelaar and colleagues [23] observed a lower alpha peak frequency and reduced beta power in burnout subjects. Similar data on reduced alpha band power in burnout individuals were observed in a resting-state condition [24]. It was revealed that individual alpha frequency (IAF) under resting state (eyes-closed condition) is linked to depressive symptoms and alpha power related to burnout [25]. A decrease in the beta band power in the anterior area associated with dysfunction of the frontal regulatory systems. At the same time theta and beta bands increased their power in the parietal association area in burned-out subjects [26].

AIM

This study aimed to examine EEG frequency changes associated with the severity of the Anxiety-Tension stage of Emotional Burnout.

The analysis of the up-to-date state in neurophysiological burnout research allows us to make several conclusions:

- a very few studies focusing on the neurophysiological aspects of emotional burnout;
- the severity of emotional burnout correlated with the modulation of the activity of brain regions involved in emotion regulation and motivational behaviours;
- the electrical activity of the brain in resting state is reflected the severity of burnout symptoms.

Considering all the above, the aim of this study was to determine the EEG pattern (spectral power characteristics at rest state) of emotional burnout formation in earlier stages. We assume that EEG frequency pattern, power spectral densities (PSD) may reflect the local process, brain area specific activity associated with emotional burnout severity.

MATERIALS AND METHODS

Sample

Initially, 752 participants (students and employees from Taras Shevchenko National University of Kyiv, National Aviation University, Kyiv, Ukraine) were recruited in the study (209 males, mean age=19.2, std=2.55; 543 females, mean age=18.28, std=2.19); however, the final sample included 624 participants due to the exclusion of data from 128 individuals with poor EEG quality and excessive artefacts.

The study was approved by the Local Ethics Committee of the Educational and Scientific Centre 'Institute of Biology and Medicine' at Taras Shevchenko National University of Kyiv. Written informed consent was obtained from each volunteer following the Declaration of Helsinki. The exclusion criteria were clinical manifestations of mental disorders or cognitive impairment, and taking psychoactive medication, drugs, or alcohol.

Psychological testing

The severity of emotional burnout was detected using the 84-item Boyko's Syndrome of Emotional Burnout Inventory (SEB) [27, 28]. Specific features of students' professional activities were taken into account in the adapted version of the test [4, 29]. SEB consists of three stages: Anxiety Tension, Resistance, and Exhaustion [27, 28]. The value of each stage is measured on a scale from 0 to 120 points: from 0 to 36 points – the stage ***is not formed*** (Anxiety Tension 1), from 37 to 60 points – the stage is ***in the process*** of development (Anxiety Tension 2), from 61 to 120 points – the stage ***is formed*** (Anxiety Tension 3).

Experiment design

EEG was recorded monopolarly using the EEG 19-channel system Neurocom (XAI-MEDICA, Ukraine) during the rest state (3 min, closed eyes condition). The silver/silver chloride electrodes were placed on the scalp at symmetrical anterior frontal (Fp1, Fp2), frontal (F3, F4, Fz, F7, F8), central (C3, C4, Cz) parietal (P3, P4, Pz), occipital (O1, O2) and temporal (T3, T4, T5, T6) recording sites according to the International 10-20 scheme. All electrodes were referenced to the interconnected ear electrodes. The interelectrode impedance levels were below 5 kΩ. The sample rate of all channels was 500 Hz.

EEG pre-processing

The EEG frequency range was split into the following bands and sub-bands: delta (1-4 Hz), theta (4-7.5 Hz), low theta (theta 1, 4-6 Hz), and high theta (theta 2, 6-7.5 Hz), alpha (7.5-13 Hz), low alpha (alpha 1, 7.5-9.5 Hz), middle alpha (alpha 2, 9.5-11 Hz), and upper alpha (alpha 3, 11-13 Hz), beta (13-35 Hz), low beta (beta 1, 13-20 Hz), and upper beta (beta 2, 20-35 Hz), gamma (35-100 Hz), low gamma (35-50 Hz), and gamma high (50-100 Hz).

Power spectral characteristics

Power distribution across frequency components composing the EEG signal describes normalized power. For each EEG channel the normalized power spectrum S(f) was calculated as the normalized square of absolute values of its Discrete Fourier Transform F(f) using FFT function (the NumPy Python package, https://numpy.org/):

$$S(f) = |F(f)|^2 / \sum_{f=0}^{f_n} |F(f)|^2$$

where f_n is selected to be a Nyquist frequency and equal to 250 Hz. We examined the normalized power spectral density (PSD) of each band/sub-band:

$$PSD(f) = \frac{|FFT(x[n])|^2}{N \cdot f_S},$$

where $FFT(x[n])$ - fast Fourier transform of the signal $x[n]$;

N - signal length;

f_S - sampling frequency.

The distribution histogram showed that the duration of the subjects' electroencephalograms varies from 3 to 5 minutes, so each signal was segmented, and the PSD was calculated on the segment from 61 to 70 seconds (Fig. 1).

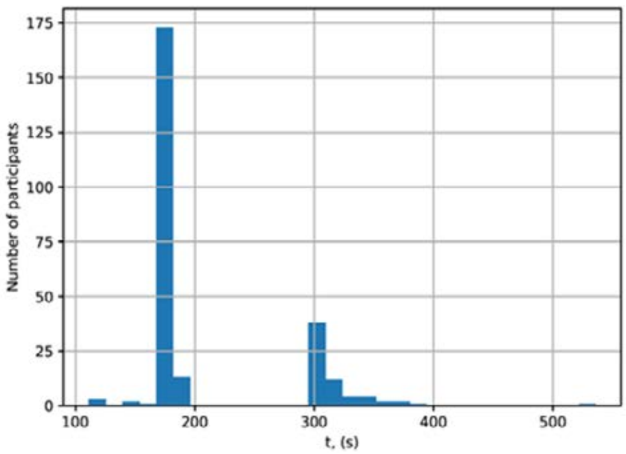

Figure 1. The distribution of the duration of the patients' electroencephalograms.

To calculate the PSD, the EEG signals were processed following steps.

(1) Creating a Hann window with a length equal to the signal length to reduce the leakage effect in the spectrum when applying the Fast Fourier Transform (FFT).

(2) Fast Fourier Transformation (FFT) of the windowed signal. The FFT transforms the signal from the time domain to the frequency domain, allowing for the analysis of its frequency components.

(3) Creating an array of frequencies corresponding to the FFT values. Linearly distributed frequency values from 0 Hz to the sampling frequency (Fs) were generated. The length of this array is equal to the length of the original signal. Within each EEG frequency band, the corresponding PSD values were calculated. Normalized power spectral density values were used instead of absolute values to account for individual differences in brain activity. After calculating the personal PSD (the example of individual PSD data present in Fig. 2), for each separate signal, and for each frequency range, this value was divided by the total PSD value for the frequency range from 1 Hz to 100 Hz.

Statistical data analysis

The Shapiro-Wilk test has shown that distributions are not normal. The non-parametric Mann–Whitney U test was used to compare two independent samples (normalized power spectral densities) to determine the difference in rank values between them for two conditions («not formed» and «in progress»; «not formed» and «formed»; «in progress» and «formed»). The significance level p=0.05 was used for all statistical tests.


```
{'delta': 38.065492139184265,
 'theta1': 11.478884815419315,
 'theta2': 10.011274389110334,
 'alpha1': 10.818941227370818,
 'alpha2': 2.5237702731522895,
 'alpha3': 4.500612680703603,
 'beta1': 8.862708973814627,
 'beta2': 9.35605618647339,
 'gammaLOW': 3.813966693900217,
 'gammaHIGH': 0.5682926208711375,
 'theta': 21.49015920452965,
 'alpha': 17.84332418122671,
 'beta': 18.218765160288015,
 'gamma': 4.382259314771356,
 'total': 100.0}
```


Figure 2. Example of normalized PSD (%) for the signal of representative subject at the Fp1 electrode for the time range from 61s to 70s.

RESULTS AND DISCUSSION

Prior to conducting the EEG study, participants were asked to assess their emotional burnout levels. According to established literature, emotional burnout syndrome is conventionally divided into three phases. The precursor and trigger mechanism of burnout syndrome is considered the Anxiety Tension phase, which includes symptoms of experiencing psychotraumatic circumstances, dissatisfaction with oneself, a feeling of hopelessness, anxiety and depression [27, 28]. In this study, the sample was split into groups according to the development of the Anxiety Tension stage. The Anxiety Tension phase had formed in 47 participants and was under development in 136 participants (Table 1).

Table 1

Distribution of Emotional Burnout Severity Across Participants

	Anxiety Tension	**Resistance**	**Exhaustion**
Normal	**589**	165	460
In Progress	**136**	363	213
Formed Phase	**47**	224	79

Power spectral characteristics

The Anxiety Tension phase, recognized as a trigger for emotional burnout, warrants particular attention in terms of detecting the early stages of the burnout development with specific EEG biomarkers. Step-by-step assessment of phase formation indicates that each stage of phase development is characterized by its own EEG profile. During the formation of the Anxiety Tension stage, changes in EEG spectral characteristics are predominantly localized to specific cortical regions and are transient in nature.

At the initial stage, an increase in spectral power density was noted in the theta 2 (frontal, F4, Fz and left posterior areas, P3, O1) and alpha1 subbands (posterior temporal area, T5–T6), as well as a local decrease in the beta 1 subband (F4, C3). With further Phase development the same direction of EEG changes is maintained at the next stage – an increase in the theta and alpha ranges and a decrease in the beta and gamma ranges. The most pronounced are formation of non-overlapping areas for the beta 1 subband (the decrease in the right hemisphere – central and parietal and posterior temporal areas) and theta 2 subband (an increase in the anterior areas of the cortex and the left temporoparietal area). A redistribution of activity occurs, which may be associated with developing new symptoms while maintaining stress effects. Steady changes in PSD within the theta 2 subbands were observed, likely reflecting the severity of the Anxiety Tension phase – the increase in two left cortex areas (frontal F7 and parietal P3) (Table 2, Fig. 3). The other changes can be considered as describing the process of transition to the next level of this stage of burnout.

Previous studies have established that higher theta power during the resting state correlates with improved performance, memory, attention, and cognitive control [30]. The frontoparietal theta phase synchronization is involved in visual working memory [31], the evaluation of choice-relevant information, and consequent behavioural decisions [32]. Frontocentral beta rhythm is engaged in cognitive control and working memory [33]. The opposite direction of those frequencies changes in the final stage of burnout phase development indicates a violation of cognitive control of higher-order cognitive processes such as cognitive control and working memory.

Revealed specified changes in frontal midline theta reflect cortical functioning namely cognitive effort, and working memory [34]. Besides this frontal midline theta reflects adaptations to uncertainty in the situations that elicit anxiety and demand cognitive control [35]. Based on these, our data allows us to make a reasonable assumption that during the formation of the studied Burnout Phase, changes in behavioural decisions occur due to the negative impact of everyday stress on the processes of memory, attention, and cognitive control.

Table 2

The significant difference in rank values between independent samples (normalized power spectral densities) for two conditions («not formed» and «in progress»; «not formed» and «formed»; «in progress» and «formed»), p<0.05

	Not formed – In Progress	Not formed – Formed	In Progress – Formed
Fp1		theta 2: –2.796974507362952	
Fp2		theta 2: –3.572864630320246	
F3		theta 2: –4.210983553428742, beta1: 2.829434636234998	
F4	beta 1: 1.6713044058101145		
F7	theta 2: –1.435791100572179	theta 2: –2.2697317781769817, alpha1: –4.997402912991037	
F8		theta2: –3.725153287926622	
Fz	theta 2: –1.6719222085352472		
C3	beta 1: 1.6054687214290988		
C4		beta 1: 2.480736446858125	
Cz		beta 1: 2.3339427697046826	
T3		theta 2: –2.2749696024416686	alpha 2: –5.064334561159228
T4		theta 1: –2.9521896726994896	
T5	alpha 1: –4.006116140936303		alpha 2: –6.104931448150229
T6	alpha 1: –3.886599291988505	alpha 2: –7.624220436881284, beta 1: 2.4219680182293244	alpha 2: –9.734279837398143
P3	theta2: –2.3462830453067154	theta2: –2.5299798264313234	
P4		alpha 2: –8.75323875848574, beta 1: 2.60392514806737, gammaLOW: 0.3509738145741228	
O1	theta 2: –1.2028691485587393		

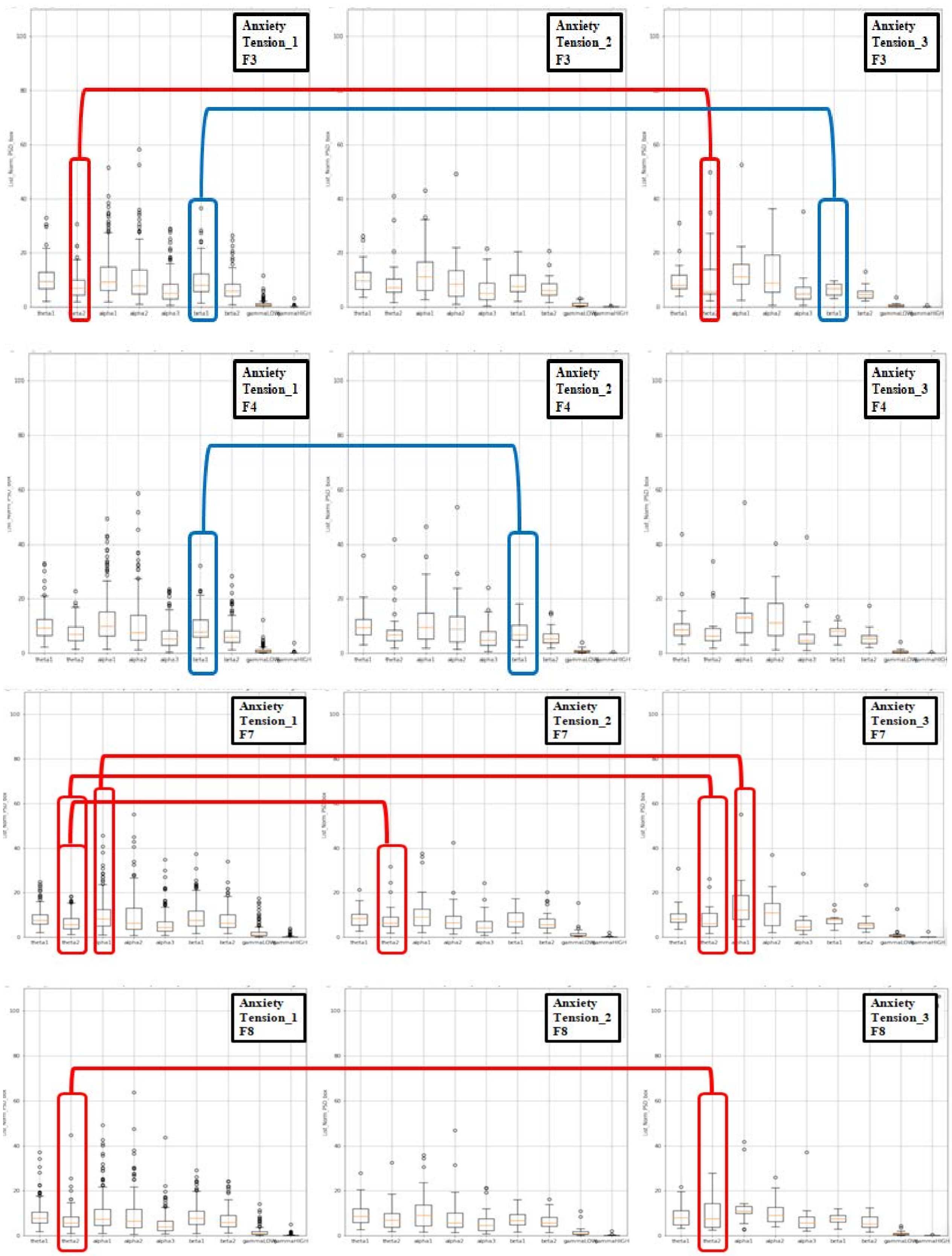

Figure 3. Frontal cortex. The significant difference in rank values between independent samples (normalized power spectral densities) for two conditions: «not formed (Anxiety Tension 1)» and «in progress (Anxiety Tension 2)»; «not formed» and «formed (Anxiety Tension 3)»; «in progress» and «formed»).

CONCLUSIONS

We propose that the complex temporal nature of functional relationships during burnout formation reflects an adaptation process to stressful conditions and subsequent resource depletion. The assessment of local cortical activity changes indicates a shift in activity in cortical areas involved in the integration of emotion and cognition. Such findings could guide the design of early screening tools based on EEG markers, enabling timely interventions to halt burnout progression.

Prospects for further research. Burnout syndrome is a significant medical and social problem. Timely diagnosis and prevention of its development is important, especially in the realities of war, when a person is under tension and constant stress. An important aspect of the prevention of burnout syndrome is understanding the essence of the formation of pathological changes, which can have destructive consequences. In the future, the study of the pathophysiological manifestations of the stages of the formation of burnout syndrome in further research provides an opportunity to substantiate and develop qualitatively new algorithms for its prevention and prevention of development in the future.

FUNDING AND CONFLICT OF INTEREST

The Authors declare no conflict of interest. The article was funded at the authors' own expense.

COMPLIANCE WITH ETHICAL REQUIREMENTS

In this study, the authors adhered to the Ethical Principles for Medical Research Involving Human Subjects, as outlined in the World Medical Association's Declaration of Helsinki (WMA, 1964), and current Ukrainian regulations. The ethics committee of the L. I. Medved's Research Centre of Preventive Toxicology, Food and Chemical Safety approved the study protocol of the Ministry of Health of Ukraine. No animals were used in the study.

AUTHOR CONTRIBUTIONS

Mushta S. A.[B, C, D, E, F]
Palamar S. P.[B, C, D, E, F]
Harmatiuk D. V.[C, D, E, F]
Popov A. O.[B, C, D, E, F]
Ferreira J. M.A.[B, C, D, E, F]
Makarchuk M.Yu.[B, C, D, E, F]
Tukaiev S. V.[A, B, C, D, E, F]

REFERENCES

1. Schaufeli, W. B. (2018). Burnout in Europe: Relations with national economy, governance, and culture. Research Unit Occupational & Organizational Psychology and Professional Learning (internal report). KU Leuven, Belgium. Retrieved from https://www.wilmarschaufeli.nl/publications/Schaufeli/500.pdf
2. Maslach, C. (2006). Understanding job burnout. In A. M. Rossi, P. Perrewe, and S. Maslach Sauter (Eds.), Stress and quality of working life: Current perspectives in occupational health (pp. 37-51). Greenwich, CT: Information Age Publishing.
3. Schaufeli, W. B., Leiter, M. P., & Maslach, C. (2009). Burnout: 35 years of research and practice. Career Development International,14(3), 204-220. doi: 10.1108/13620430910966406
4. Tukaiev, S. V., Vasheka, T. V., & Zyma, I. G. (2013). Psychological and neurophysiological aspects of the emotional burnout development. Actual aspects of internal medicine, 86-107.
5. Grossi, G., Perski, A., Osika, W., &Savic, I. (2015). Stress-related exhaustion disorder–clinical manifestation of burnout? A review of assessment methods, sleep impairments, cognitive disturbances, and neuro-biological and physiological changes in clinical burnout. Scandinavian journal of psychology, 56(6), 626-636. doi: https://doi.org/10.1111/sjop.12251
6. Brenninkmeyer, V., Van Yperen, N. W., &Buunk, B. P. (2001). Burnout and depression are not identical twins: is decline of superiority a distinguishing feature?. Personality and individual differences, 30(5), 873-880. doi: https://doi.org/10.1016/S0191-8869(00)00079-9
7. Melamed, S., Shirom, A., Toker, S., Berliner, S., & Shapira, I. (2006). Burnout and risk of cardiovascular disease: Evidence, possible causal paths, and promising research directions. Psychological bulletin, 132(3), 327-353. doi: http://dx.doi.org/10.1037/0033-2909.132.3.327
8. Tukaev, S. V., Vasheka, T. V., & Dolgova, O. M. (2013). The Relationships Between Emotional Burnout and Motivational, Semantic and Communicative Features of Psychology Students.Procedia-Social and Behavioral Sciences,82, 553-556.doi: 10.1016/j.sbspro.2013.06.308
9. Tukaev, S., Palamar, B., Vasheka, T., & Mishyiev, V. (2020). Sindrom emotsional'nogo vygoraniya. Psikhofiziologicheskiye aspekty [Burnout syndrome. Psychophysiological aspects] Psychiatry, Psychotherapy and Clinical Psychology, 11(4), 791-801

10. Heinemann, L. V., & Heinemann, T. (2017). Burnout research: Emergence and scientific investigation of a contested diagnosis. Sage Open, 7(1), 2158244017697154. doi: https://doi.org/10.1177/2158244017697154
11. Deligkaris, P., Panagopoulou, E., Montgomery, A. J., & Masoura, E. (2014). Job burnout and cognitive functioning: A systematic review. Work & stress, 28(2), 107-123. doi: 10.1080/02678373.2014.909545
12. Danhof-Pont, M. B., van Veen, T., & Zitman, F. G. (2011). Biomarkers in burnout: a systematic review. Journal of psychosomatic research, 70(6), 505-524. doi: https://doi.org/10.1016/j.jpsychores.2010.10.012
13. Tei, S., Becker, C., Kawada, R., Fujino, J., Jankowski, K. F., Sugihara, G., … & Takahashi, H. (2014). Can we predict burnout severity from empathy-related brain activity?. Translational psychiatry, 4(6), e393. doi: 10.1038/tp.2014.34
14. Durning, S. J., Costanzo, M., Artino Jr, A. R., Dyrbye, L. N., Beckman, T. J., Schuwirth, L., … & van der Vleuten, C. (2013). Functional neuroimaging correlates of burnout among internal medicine residents and faculty members. Frontiers in psychiatry, 4, 131. doi: 10.3389/fpsyt.2013.00131
15. Leech, R., & Smallwood, J. (2019). The posterior cingulate cortex: Insights from structure and function. Handbook of clinical neurology, 166, 73-85. doi: https://doi.org/10.1016/B978-0-444-64196-0.00005-4
16. Blix, E., Perski, A., Berglund, H., & Savic, I. (2013). Long-term occupational stress is associated with regional reductions in brain tissue volumes. PLoS One, 8(6), e64065. doi: 10.1371/journal.pone.0064065
17. Gavelin, H. M., Neely, A. S., Dunås, T., Eskilsson, T., Järvholm, L. S., & Boraxbekk, C. J. (2020). Mental fatigue in stress-related exhaustion disorder: Structural brain correlates, clinical characteristics and relations with cognitive functioning. NeuroImage: Clinical, 27, 102337. doi: 10.1016/j.nicl.2020.102337
18. Arias-Carrión, O., Stamelou, M., Murillo-Rodríguez, E., Menéndez-González, M., &Pöppel, E. (2010). Dopaminergic reward system: a short integrative review. International archives of medicine, 3(1), 24. doi: https: //doi.org/10.1186/1755-7682-3-24
19. Abe, K., Tei, S., Takahashi, H., & Fujino, J. (2022). Structural brain correlates of burnout severity in medical professionals: A voxel-based morphometric study. Neuroscience Letters, 772, 136484. doi: https://doi.org/10.1016/j.neulet.2022.136484
20. Koenigs, M., & Grafman, J. (2009). The functional neuroanatomy of depression: distinct roles for ventromedial and dorsolateral prefrontal cortex. Behavioural brain research, 201(2), 239-243. doi: https://doi.org/10.1016/j.bbr.2009.03.004
21. Savic, I., Perski, A., & Osika, W. (2018). MRI shows that exhaustion syndrome due to chronic occupational stress is associated with partially reversible cerebral changes. Cerebral Cortex, 28(3), 894-906. doi: https://doi.org/10.1093/cercor/bhw413
22. Roberts, B. L., & Karatsoreos, I. N. (2021). Brain-body responses to chronic stress: a brief review. Faculty reviews, 10, 83. doi: https://doi.org/10.12703/r/10-83
23. VanLuijtelaar, G. V., Verbraak, M., Bunt, M. V. D., Keijsers, G., & Arns, M. (2010). EEG findings in burnout patients. The Journal of Neuropsychiatry and Clinical Neurosciences, 22(2), 208-217. doi: 10.1176/jnp.2010.22.2.208
24. Golonka, K., Gawlowska, M., Mojsa-Kaja, J., & Marek, T. (2019). Psychophysiological characteristics of burnout syndrome: Resting-state EEG analysis. BioMed research international, 2019. Article ID 3764354. doi: 10.1155/2019/3764354
25. Tement, S., Pahor, A., & Jaušovec, N. (2016). EEG alpha frequency correlates of burnout and depression: The role of gender. Biological psychology, 114, 1-12. doi: 10.1016/j.biopsycho.2015.11.005
26. Yakovenko, E. A., Rem, A. V., Surushkina, S. Y., & Chutko, L. S. (2021). Electroencephalographic Signs of Emotional Burnout Syndrome. Neuroscience and Behavioral Physiology, 51(2), 155-157. doi: https://doi.org/10.1007/s11055-021-01051-z
27. Vodopyanova, N. E., & Starchenkova, E. S. (2009). Syndrome of burnout: diagnostics and prevention.
28. Boyko, V. V. (1999). Syndrome of» emotional burnout» in professional communication.
29. Vasheka, T. V., & Tukaiev, S. V. (2011). Determinants of emotional burnout of students studying psychology in learning. Problems of General and Educational Psychology, 13(6), 47-55.
30. Tan, E., Troller-Renfree, S. V., Morales, S., Buzzell, G. A., McSweeney, M., Antúnez, M., & Fox, N. A. (2024). Theta activity and cognitive functioning: Integrating evidence from resting-state and task-related developmental electroencephalography (EEG) research. Developmental Cognitive Neuroscience, 67, doi: 101404. https://doi.org/10.1016/j.dcn.2024.101404
31. Kawasaki, M., Kitajo, K., & Yamaguchi, Y. (2014). Fronto-parietal and fronto-temporal theta phase synchronization for visual and auditory-verbal working memory. Frontiers in psychology, 5, 200.doi: https://doi.org/10.3389/fpsyg.2014.00200
32. Rawle, C. J., Miall, R. C., & Pramstra, P. (2012). Frontoparietal theta activity supports behavioral decisions in movement-target selection. Frontiers in Human Neuroscience, 6, 138. https://doi.org/10.3389/fnhum.2012.00138
33. Morris, A. T., Temereanca, S., Zandvakili, A., Thorpe, R., Sliva, D. D., Greenberg, B. D., … & Jones, S. R. (2023). Fronto-central resting-state 15-29 Hz transient beta events change with therapeutic

transcranial magnetic stimulation for posttraumatic stress disorder and major depressive disorder. Scientific Reports, 13(1), 6366.doi: https://doi.org/10.1038/s41598-023-
34. Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. Trends in cognitive sciences, 18(8), 414-421. doi: https://doi.org/10.1016/j.tics.2014.04.012
35. Cavanagh, J. F., & Shackman, A. J. (2015). Frontal midline theta reflects anxiety and cognitive control: meta-analytic evidence. Journal of physiology-Paris, 109(1-3), 3-15. doi: https://doi.org/10.1016/j.jphysparis.2014.04.003

Резюме

ПАТТЕРН ЧАСТОТ ЕЕГ ЯК НЕЙРОФІЗІОЛОГІЧНИЙ МАРКЕР ЕМОЦІЙНОГО ВИГОРАННЯ. ФОРМУВАННЯ СТАДІЇ НАПРУГИ

Семен А. Мушта[1], Світлана П. Паламар[2], Дмитро В. Гарматюк[1], Антон О. Попов[1,5], Жоао М. Алвес Феррейра[3], Микола Ю. Макарчук[4], Сергій В. Тукаєв[4]

[1]Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», м. Київ, Україна
[2]Київський столичний університет імені Бориса Грінченка, м. Київ, Україна
[3]Університет Коїмбри, м Коїмбра, Португалія
[4]Київський національний університет імені Тараса Шевченка, м. Київ, Україна
[5]Український Католицький Університет, м. Львів, Україна

Вступ. У статті розглянуто питання частоти паттерна ЕЕГ як маркера емоційного вигорання мозку при формуванні стадії тривоги та напруження. Вигорання розвивається поступово і часто залишається непоміченим, з симптомами, які можуть проявлятися роками та призвести до значних психічних і поведінкових змін. Незважаючи на його вплив, процеси, що лежать в основі вигорання, залишаються в основному невідомими через відсутність спеціалізованих досліджень, які б ідентифікували конкретні біомаркери. Раннє виявлення синдрому вигорання, особливо при появі критичних симптомів, має важливе значення.
Мета. Проаналізувати та вивчити зміни частоти ЕЕГ, пов'язані з тяжкістю тривожно-напруженої стадії емоційного вигорання.
Матеріали та методи. Ступінь вираженості емоційного вигорання виявляли за допомогою 84-пунктового опису синдрому емоційного вигорання (SEB) Бойка. SEB складається з трьох стадій: тривоги, напруги, резистентності та виснаження. Збір даних проведено шляхом метааналізу емпіричних даних. Загалом 752 учасники, у тому числі студенти та співробітники Київського національного університету імені Тараса Шевченка (209 чоловіків, середній вік=19,2; 543 жінки, середній вік – 18,28), були оцінені за допомогою 84-пунктового опису синдрому емоційного вигорання Бойка.
Результати. Дані ЕЕГ записували під час 3-хвилинного стану спокою із закритими очима та аналізували вільні від артефактів сегменти з усіх діапазонів частот (0,2-45 Гц). Нормалізовані спектральні щільності потужності (СЩП) були розраховані, зосереджуючись на 61-70 секундному сегменті записів. Результати виявили пов'язані з вигоранням зміни в спектральних характеристиках, пов'язаних зі стадією тривоги-напруги, зі значними змінами, що спостерігалися в смузі тета 2 (фронтальна та ліва скронево-тім'яна кора), альфа-смузі 2 (права тім'яно-скронева кора) та бета-смузі 1 (ліва фронтальна – центральна – права тім'яна вісь).
Висновки. Стадія тривоги та напруги в першу чергу впливає на процеси, пов'язані з короткочасною пам'яттю та зосередженою увагою, створюючи потенційну основу для ранньої ідентифікації вигорання за допомогою нейрофізіологічних маркерів. Ми припускаємо, що складний часовий характер функціональних зв'язків під час формування професійного вигорання відображає процес адаптації до стресових умов і подальше виснаження ресурсів. Оцінка локальних змін коркової активності відзначає зміщення активності в коркових областях, залучених до інтеграції емоцій та пізнання. Такі висновки можуть керувати розробкою інструментів раннього скринінгу на основі маркерів ЕЕГ, що дозволить своєчасно втручатися, щоб зупинити прогресування вигорання.

Ключові слова: **емоційне вигорання, тривожне напруження, ЕЕГ, спектральна щільність потужності**

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