

THE CONJUGATION OF PSYCHOLOGICAL INDICATORS AND THE LEVEL OF CONSTANT POTENTIAL OF THE BRAIN FOR PARTICIPANTS IN MODERN ARMED CONFLICT (PILOT STUDY)

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RESUME

Rationale. The specificity of injuries in combatants determines the feasibility of studying the relationship between the state of cerebral energy metabolism (CEM) and changes in the mental sphere to establish the role of adaptive reactions of the nervous system in the development of psychogenic lesions of various levels.

The aim. Compare changes in psychological indicators and the level of constant brain potential in combatants.

Materials and methods. Fifty four combatants were examined. Used methods of neuroenergy mapping, psychological diagnosis.

Results. Compared with the comparison group, combatants had the increased average DC-potential level ($X_{av.}$) (69.7 % and 17.6 %, $p = 0.031$, respectively). An increase in the local DC-potential level in the central and right frontal, the right temporal, central, and left parietal parts of the brain (12.3 (8.1–20.3); 10.1 (7.8–34.4); 8.6 (4.2–17.4); 5.8 (1.1–15.2); 5.4 (3.0–15.3), and 0.8 (-3.1–4.3); -5.8 (-12.1–5.1); -2.2 (-4.9–4.3); 1.7 (-0.7–5.4); 0.1 (-4.9–2.8) mV, $p = 0.005$, 0.007, 0.011, 0.003, 0.004, respectively) was registered. More than 58.8 % of the combatants had an adaptation violation in the form of a rigid reaction to stress. When modeling physical and emotional stress, correlation ties between the DC-potential level were established in the post-hypertension period and indicators of the test of visual perception ($r_s = 0.52$, $p = 0.018$), the symptom of acute stress disorder (ASD) "Event of the injury" ($r_s = 0.52$ $p = 0.009$; $r_s = 0.54$ $p = 0.011$; $r_s = 0.53$ $p = 0.017$, respectively).

Limitations. The study is limited by the sample of patients and the lack of clinical characteristics of examined combatants, taking into account psychoneurological conditions.

Conclusion. Violation of physiological adaptation to combat stress is manifested by a rigid reaction of the DC-potential level ($X_{av.}$). During functional trials, the conjunction of the reactivity of the cerebral energy exchange with the severity of the symptom of the "Event of the injury", an indicator of visual perception, reflecting the vulnerability of the right hemisphere, which leads in the development of adaptation and stress.

Key words: combatants, psychological features, DC-potential level, violation of adaptation

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СОПРЯЖЕННОСТЬ ПСИХОЛОГИЧЕСКИХ ПОКАЗАТЕЛЕЙ И УРОВНЯ ПОСТОЯННОГО ПОТЕНЦИАЛА ГОЛОВНОГО МОЗГА У УЧАСТНИКОВ СОВРЕМЕННОГО ВООРУЖЕННОГО КОНФЛИКТА (ПИЛОТНОЕ ИССЛЕДОВАНИЕ)

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РЕЗЮМЕ

Обоснование. Специфика травм участников боевых действий (БД) определяет целесообразность изучения связи состояния церебрального энергетического обмена (ЦЭО) и изменений в психической сфере для установления роли адаптивных реакций нервной системы в развитии психогенных поражений различного уровня.

Цель исследования. Сопоставить изменения психологических показателей и уровня постоянного потенциала головного мозга у участников БД.

Материалы и методы. Обследовано 54 участника БД. Применяли методы нейроэнергокартирования, психологической диагностики.

Результаты. У участников БД при сопоставлении с группой сравнения преобладал повышенный усредненный УПП (Хср.) (69,7 % и 17,6 %, $p = 0,031$, соответственно). Зарегистрировано увеличение локальных УПП в центральном и правом лобном, правом височном, центральном и левом теменных отделах мозга ((12,3 (8,1–20,3); 10,1 (7,8–34,4); 8,6 (4,2–17,4); 5,8 (1,1–15,2); 5,4 (3,0–15,3); и 0,8 (-3,1–4,3); -5,8 (-12,1–5,1); -2,2 (-4,9–4,3); 1,7 (-0,7–5,4); 0,1 (-4,9–2,8) мВ при $p = 0,005, 0,007; 0,011; 0,003; 0,004$, соответственно)). У более 58,8 % комбатантов определено нарушение адаптации в виде ригидной реакции на стресс. При моделировании физического и эмоционального стресса, в постгипервентиляционном периоде установлены корреляционные связи между УПП Хср. и показателями теста на зрительное восприятие ($r_s = 0,52, p = 0,018$), симптома острого стрессового расстройства (ОСР) «Событие травмы» ($r_s = 0,52, p = 0,009; r_s = 0,54, p = 0,011; r_s = 0,53, p = 0,017$, соответственно).

Ограничения исследований. Исследование ограничено выборкой пациентов, отсутствием клинической характеристики обследованных с учетом психоневрологических состояний.

Заключение. Нарушение физиологической адаптации к боевому стрессу проявляется ригидной реакцией УПП при проведении функциональных проб, сопряженностью реактивности ЦЭО с выраженностью симптома «Событие травмы», показателем зрительного восприятия, отражающим уязвимость правого полушария, ведущего в развитии адаптации и стресса.

Ключевые слова: участники боевых действий, психологические особенности, уровень постоянного потенциала, нарушение адаптации

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INTRODUCTION

One of the key objectives of the Russian Federation's national development strategy is to preserve the population, promote health, and improve the well-being of citizens, including by supporting families and increasing the satisfaction of military personnel with medical rehabilitation, training, and employment opportunities by 2030¹. Since 2022, professionals in the fields of neurology, psychiatry, and clinical psychology have been closely monitoring the psychological reactions of military personnel resulting from exposure to numerous physical and emotional stressors that can lead to various stress-induced mental health issues. Due to the demanding nature of their work and the long-term effects of injuries, these conditions significantly impact the mental health and overall well-being of combatants [1–3]. Previously, it has been established that the clinical and psychological profile of combatants with combined injuries (shrapnel wounds and concussions) is characterized by reactions to severe stress and adaptive disorders (F43), as well as anxiety and depressive symptoms, along with mild cognitive impairment manifested through changes in neuropsychological indicators. These findings suggest vulnerability of neurons in specific regions of the brain, including the hippocampus, frontal, temporal, occipital, and parietal lobes, to metabolic damage and hypoxia [4, 5].

It has been established that symptoms of chronic stress conditions occur as a result of a systemic neuroendocrine response to traumatic events, which is accompanied by damage to the body's self-regulation mechanisms, the accumulation of "allostatic load", and subsequent depletion of adaptive reserves. These factors can be considered the main cause of increased brain functional activity and, consequently, its metabolic processes. This can lead to the development of acute stress disorders (ASD), post-traumatic stress disorders (PTSD) and complex post-traumatic stress disorders (CPTSD) as well as cognitive impairments [6–10].

Despite the available literature on the occurrence of acute and delayed stress-related disorders (according to ICD-10) among combatants [11–14] and mild cognitive impairment [4], there is a lack of data on the functional activity of the brain, specifically, on the characteristics of cerebral energy metabolism in relation to indicators that characterize the current psycho-emotional state and cognitive function. This study aims to establish the characteristics of changes in psychological indicators due to CEM reactivity, given that in the post-traumatic period following blast injuries and combat-related mental trauma, physical and mental health impairments occur among

the injured, causing difficulties in the process of readjustment and re-socialization [15].

AIM

To compare changes in psychological indicators and the level of stable brain potential in combatants.

MATERIALS AND METHODS

In a clinical setting, a study was conducted on 54 male military personnel serving under contract (mean age 38.0 (33.0–45.0) years; duration of service in the conflict zone 20.0 (7.0–24.0) months). These combatants had participated in extreme types of military activities in the conflict zone, which involved exposure to a wide range of stressors. As part of their duties, these personnel were required to perform specialized tasks that involved the use of new knowledge, communication, reconnaissance tools, weapons, and equipment. The intensity of their professional activities was significantly increased under conditions of ongoing danger, high levels of responsibility, and uncertainty.

The comparison group consisted of 30 conscripted men, who were comparable in age (mean age 39.5 (34.0–46.5) years), had not participated in combat operations, had not reported any memory or attention problems, had no history of traumatic brain injury, and were free from acute or chronic diseases (in the acute phase) at the time of the study. Inclusion criteria for the study included male sex, informed written consent to participate, age between 25 and 55 years old, and conscription status. Exclusion criteria included the presence of any pathology that could influence the results of the cognitive evaluation (low-grade fever, side effects of medication, or chronic cardiovascular conditions leading to significant changes in cerebral vascular reactivity). All participants had no history of stress-related mental disorders.

An electrophysiological method for recording DC potential, known as the neuroenergy mapping (NEM) method, employed in conjunction with functional afferent testing (FAT) procedures. These tests included three-minute hyperventilation (HV) to model physical stress, a post-hyperventilation interval (PHVP) of 3 minutes, and a quick verbal response test (TQVA) to simulate emotional cognitive stress. The studies were conducted using a hardware-software complex for electrical activity topographic mapping, "Neuro-KM" (TU 9442-001-28910376-2008, registration certificate No. FSR 2009/05370, certificate of conformity No. ROSS RU.0001.11IM25, Moscow). This device features 12 channels, including

¹ On the National Development Goals of the Russian Federation for the Period up to 2030 and for the Future up to 2036: Presidential Executive Order No. 309 of May 7, 2024. Official Internet Portal of Legal Information; May 7, 2024. URL: <https://normativ.kontur.ru/document?moduleId=1&documentId=470566>

Fz – frontal central, Fd – frontal right, Fs – frontal left, Cz – central, Cd – central right, Cs – central left, Pz – central parietal, Pd – parietal right, Ps – parietal left, Oz – occipital, Td – temporal right, Ts – temporal left. The level of energy metabolism intensity was calculated for all regions in each subject using the average DC potential Xav. The average DC potential is the average of the 12-lead DC potential. Since DC potentials in monopolar leads are summed, this indicator reflects the potential difference between the average head potential and the hand (reference electrode). The average DC potential has similar characteristics to the DC potential measured in a monopolar lead, but it refers to an integrated (average) evaluation of brain energy metabolism [16]. Using the Td-Ts gradient, interhemispheric temporal asymmetry in energy metabolism was established, and Cd-Cs central asymmetry. Active electrodes were placed on the head following the 10x20 configuration, and the reference electrode was positioned on the right wrist [16]. Based on changes in the DC potential, the level of CEM intensity was assessed. Based on the deviation of the DC potential averaged over all electrodes (DC potential Xav.) from the initial value (background level) during functional tests, a variant of the adaptive response was used [17, 18]. Diagnosis of ASD and PTSD was conducted using questionnaires developed by Kotenev I.O. for diagnosing symptoms of ASD and PTSD [19, 20], and the Mississippi Scale for PTSD (military and civilian versions) [21]. To assess the quantitative parameters of the frequency and duration of participation in hostilities, the Combat Exposure Scale (CES) developed by T. Keane was used [22]. The state of cognitive functions was assessed using a set of neuropsychological methods based on the scheme developed by A.R. Luria [4, 23, 24]. A clinical psychologist assessed the state of intelligence, memory (tests “4th extra”, “broken window”, “triple counting”, “simple counting operations”, “selecting opposites”, “10 words”, “memorizing groups of pictures with threefold reproduction”), praxis (“fist-edge-palm”, Head’s test, Ozeretsky’s test), gnosis (crossed out, superimposed images, non-speech noises and familiar melodies, showing a given finger by pattern and by name, Semago M.M. test “Unfinished images”) and speech (understanding logical-grammatical structures, ordinal counting from 1 to 10, listing days of the week, months, completing well-known proverbs, repeating sounds, series of sounds, words and phrases) [23]. The success of each test was conditionally rated on a 4-point scale: 0 points – copes with task (no errors); 1 point – mild impairment (1 error); 2 points – moderate impairment (2 errors); 3 points – severe impairment (3 or more errors).

Data were processed using Microsoft Office 2003 software (in Windows XP) and Jamovi statistical software version 2.3. Due to the non-normal distribution of variables in the sample (Shapiro – Wilk test), comparison of quantitative variables was performed

using the non-parametric Mann – Whitney U-test. The results are presented as median (Me), interquartile range (P25–P75), and intensive (per 100 examined) and extensive (%) indicators. Statistical significance of differences between percentages was calculated using the Fisher’s angular transformation method. Differences were considered statistically significant at $p < 0.05$. Correlation between variables was assessed using Spearman’s correlation coefficient (r_s), and a non-parametric Mann – Whitney U-test was used to compare samples (with Bonferroni correction applied if necessary).

The diagnosis was made in accordance with the criteria set forth in the International Classification of Diseases (ICD-10). Patients’ examinations were conducted in accordance with the ethical standards outlined in the World Medical Association’s Declaration of Helsinki “Ethical Principles for Medical Research Involving Human Subjects” (2013), and the “Good Clinical Practice Guidelines” (approved by Order of the Ministry of Health of the Russian Federation No. 200n dated April 1, 2016), with informed consent obtained from participants prior to their involvement in the study, as per the protocol approved by the local ethics committee (Protocol No. 5 dated March 21, 2023).

RESULTS

Determination of the level of CEM intensity in combatants revealed that increased values of DC potential Xav. occurred in 69.7 % of cases. In 30.3 % of cases, the values of DC potential Xav. corresponded to normal levels. In the comparison group, individuals with normal DC potential Xav. dominated (73.9 %, $p = 0.02$). Moreover, in the group of combatants, increased DC potential Xav. statistically significantly predominated when compared to those in the comparison group (69.7 % vs. 17.6 %, $p = 0.03$). DC potential indicators characterizing ultra-slow activity of the brain were statistically significantly higher in combatants in all frontal (Fpz, Fd, Fs, $p = 0.01$; 0.0004; 0.001, respectively), central (Cz, Cd, Cs, $p = 0.0004$; 0.00001; 0.0003, respectively), central and left parietal (Pz, Ps, $p = 0.003$; 0.002, respectively), and right temporal (Td, $p = 0.01$) leads when compared to the comparison group (Fig. 1). This, to a greater extent, may be associated with an increase in the functional activity of non-specific reticular-limbic-cortical neural connections in the relevant areas of the brain. The measured values of DC potential Xav. indicators suggested a moderate increase in CEM in combatants, reflecting a state of cerebral acidosis [25]; in the comparison group, a normal level of CEM was observed (18.5 (10.3–33.4) mV vs. 8.0 (5.3–12.9) mV, $p = 0.001$).

By calculating the local DC potential (DC potential#), the intensity of energy processes in different brain regions was determined relative to the average

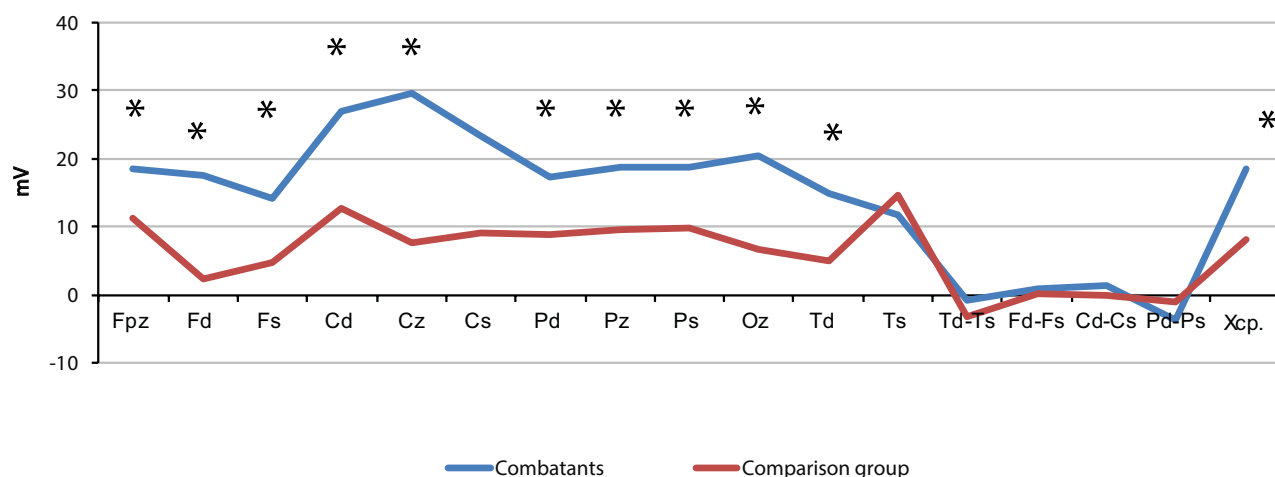


FIG. 1.
Distribution of the DC-potential level in the studied groups

* – differences are statistically significant between the groups according to the Mann – Whitney test, $p < 0.05$.

level of CEM (DC potential Xav.). Figure 2 clearly shows an increase in the DC potential# in combatants compared to the comparison group in the central and right frontal (Fpz# and Fd#, $p = 0.003$; 0.008 , respectively), right temporal (Td#, $p = 0.002$), central and left parietal (Pz# and Ps#, $p = 0.06$; 0.002 , respectively) with a simultaneous decrease in the left frontal (Fs, $p = 0.02$), central (Cd#, Cz#, Cs#, $p = 0.03$; 0.05 ; 0.01 , respectively), right parietal (Pd, $p = 0.001$) and occipital (Oz#) parts of the brain ($p = 0.02$, respectively). The detected increase in the DC potential# in combatants may indicate a disruption in the reactivity of the cortex in the aforementioned areas, due to increased blood flow and increased excitability of these regions [25].

Conducting functional tests allowed us to identify inadequate responses to afferent stimuli in most participants. The participants were found to exhibit a predominance of rigid responses to physical (HV, in 76.4 % of cases) and emotional (TQVA, in 41.3 % of cases) stressors, indicating a disruption of adaptation mechanisms. Depending on the type of stressor, the patterns of adaptive responses were distributed as follows: individuals with rigid responses to HV were statistically significantly greater (on average, 1.8 times greater) than those with responses to TQVA ($p < 0.05$). Additionally, in the combatant group, compared to the comparison group, there was a statistically significant increase in the percentage of participants with perverted stress responses ($p < 0.05$). However, no such patterns were observed in the comparison group (Table 1).

Adaptive abilities were assessed based on the nature of recovery of DC potential Xav. to its baseline

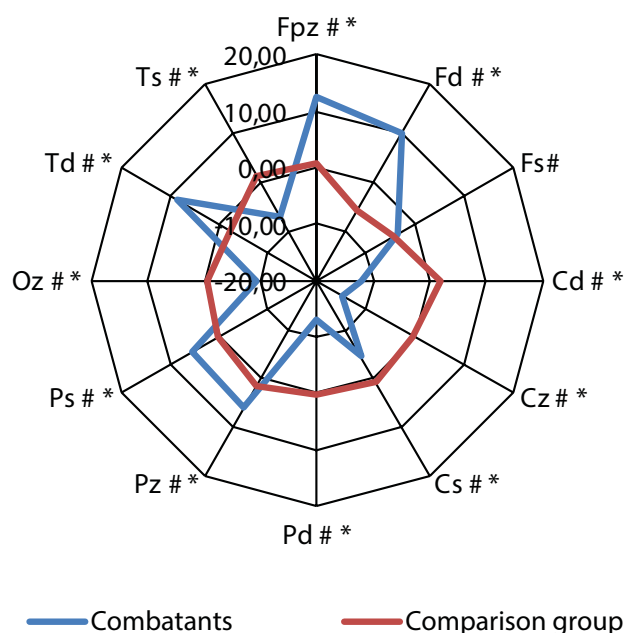


FIG. 2.
Distribution of the DC-potential level (#) in groups of combat participants and comparison

* – differences are statistically significant between the groups according to the Mann – Whitney test, $p < 0.05$

TABLE 1

THE PROPORTION OF INDIVIDUALS WITH DIFFERENT VARIANTS OF ADAPTIVE RESPONSES DURING FUNCTIONAL TESTS SIMULATING PHYSICAL AND EMOTIONAL STRESS, %

Adaptive response variant	Combatants	Comparison group
Moderate increase in DC potential Xav. (adequate reaction)	<u>11.8±4.3#</u> 23.5±5.7#	<u>26.0±8.1#</u> 37.0±8.8
No significant changes in DC potential Xav. (rigid reaction)	<u>76.4±5.7*</u> 41.3±6.7	<u>60.7±8.9</u> 43.5±9.1
Pronounced increase in DC potential Xav. (excessive reaction)	<u>0</u> 11.7±4,3	<u>8.8±5.1</u> 13.0±6.1
Decrease in DC potential Xav. (perverted reaction)	<u>11.8±4.3#</u> 23.5±5.7#	<u>4.4±3.7</u> 6.5±4.5

Note. 1. Above the line – proportion of individuals with reaction to HV, below the line – proportion of individuals with reaction to TQVA. 2. * – differences are statistically significant between rigid reactions depending on the type of stressor, $p < 0.05$. # – differences are statistically significant between adaptive response variants, $p < 0.05$.

values during PHVP. In 64.7 % of cases, the combatants showed a statistically significant ($p < 0.05$) predominance of a rigid response pattern, which is typical for asthenic conditions. At the same time, full or partial recovery of DC potential Xav. (an adequate response) was observed in only 5.9 % of cases, while a significant increase of DC potential Xav. (a perverted reaction) occurred in 11.7 %, and a decrease (an excessive reaction) in 17.7 %.

The results of the neuropsychological assessment are consistent with previous findings [4] and enable us to identify the most vulnerable cognitive functions in combatants compared to the control group: categorical reasoning, short-term auditory-verbal, visual-spatial, and long-term memory, as well as repetition of speech (repetition of disjunctive sound pairs and oppositional phonemes) and repetition of words and phrases ((0.0 (0–1.0) points; 0.5 (0–1.0) points; 1.0 (0–1.0) points; 3.0 (1.0–3.0) points; 1.0 (0–1.0) points; 0 (0–0) points; and 0 (0–0) points; 0 (0–0) points; 0 (0–1) points; 1.0 (1.0–2.0) points; 0 (0–0) points; 0 (0–0) points; at $p = 0.03$; 0.008; 0.005; 0.0001; 0.002; 0.02, respectively)). The manifestation of a stress response in combatants, as assessed using the Kotenev I.O. questionnaire, was characterized by the presence of signs of ASD in 32 % of cases, and increased values of indicators associated with the development of ASD (risk group) in 26 % of cases, with an overall score for ASD symptoms of 121.0 (87.0–138.0) points. This suggests that 58 % of individuals in this group have a high risk of developing delayed forms of stress-related disorders. This view is supported by the diagnosis of PTSD symptoms, as assessed by the Kotenev I.O. method, in 44 % of participants, with a total score

for PTSD symptoms of 119.5 (87.0–132.0) points, indicating an elevated level of exposure to combat-related trauma. The severity of indicators that characterize symptoms characteristic of PTSD, as measured by the Mississippi Scale, was also recorded. This confirms the susceptibility of the individuals under study to an increased risk of developing PTSD and impaired social adjustment (83.0 (65.0–93.0) points), even with a moderate level of combat-related experience (15.0 (10.0–17.0) points).

The correlation analysis was used to determine the relationship between the changes in mental state and parameters of deviation of DC potential Xav from its baseline value during functional testing. A statistically significant positive correlation was found between the “Unfinished Images” test score (Semago M.M.) and the change in DC potential during TQVA ($r_s = 0.52$, $p = 0.018$), suggesting a relationship between severity of visual perceptual disorders and excessive enhancement of CEM during modeling of emotional cognitive stress. Additionally, a correlation was observed between the symptom characteristic of ASD “Trauma event” and DC potential Xav. during HV, PHVP, and TQVA ($r_s = 0.52$, $p = 0.009$; $r_s = 0.54$, $p = 0.011$; $r_s = 0.53$, $p = 0.017$, respectively). This indicates that the stronger fixation on traumatic combat event is associated with more significant inadequacy in adaptive response of CEM to stress load.

DISCUSSION

During a pilot study of combatants, a moderately pronounced increase in CEM was found in the frontal

(central and right), temporal (right), parietal (central and left) regions of the brain, relative to the average level of neuroenergy metabolism. This increase was due to an imbalance in inhibition-excitation processes in the cerebral cortex. According to literature data, right-hemisphere dominance in the frontotemporal region may be associated with disorders in adaptive emotional and social behavior. These disorders can manifest as weakened self-control over activities, decreased attention, inadequate emotional reactions, and visual-spatial relationships [25–27]. In addition, increased CEM in the right hemisphere has also been linked to a predisposition to both constructive and destructive forms of aggression [26, 27].

The study of the adaptation to stress through functional testing has shown that the majority of combatants under examination have a disruption in CEM reactivity, manifested as an inadequate and rigid response to hypoxic stress and emotional cognitive stress (absence of changes in background DC potential Xav.), resulting in the development of neurodynamic impairments in cognitive functions and asthenovegetative reactions [18]. The features of these CEM changes align with the findings from psychological evaluation, which have identified symptoms of stress-related disorders, impairments in categorical thinking, memory, and speech repetition (primarily affecting motor aphasia, both afferent and efferent). Statistically significant correlations were identified between the ASD symptom “Trauma event” and DC potential Xav. during HV, PHVP, and TQVA. This likely indicates that brain metabolism is unable to adequately respond to the general adaptation syndrome in the face of personality changes observed in ASD. These changes are characterized by a pronounced symptom known as “Trauma event” (according to Kotenev I.O.). The revealed association between the indicator of the “Unfinished images” test (Semago M.M.) and the change in DC potential Xav. during the functional testing of emotional cognitive stress modeling characterizes an inappropriate post-stress change in CEM in combination with impaired visual perception of artistic images, indicating an insufficient functioning of the right hemisphere, with excessive enhancement of neuroenergy metabolism in response to emotional stress. The identified associations between DC potential parameters and visual gnosis and the indicator of severity of the ASD symptom characteristic of “Trauma event” (according to Kotenev I.O.), focus attention on the role of disturbances in adaptive neurovegetative responses of the body in the development of cognitive and behavioral problems in combatants.

As the combatants under examination continue their professional activities within the ongoing modern armed conflict, it is necessary to conduct further research on the long-term consequences of sustained injuries. Therefore, the results of this pilot study justify the continuation of work on studying mental

disorders among combatants to prevent and treat delayed and latent stress-related disorders. This includes screening individuals at risk of post-traumatic stress disorder (PTSD), implementing methods of activity participation, psycho- and drug therapy, and utilizing virtual and augmented reality technologies. Additionally, biofeedback techniques may be used to identify neurophysiological features that could be utilized in developing personalized technologies for diagnosing and treating psychoneurological conditions. These technologies could increase the effectiveness of combatant adaptation by enhancing their personal resources.

Limitations

The study is limited due to the small sample size of patients and the lack of detailed information on the clinical characteristics of the combatants under examination, which includes psychoneurological factors.

CONCLUSION

In combatants, a negative change in CEM was detected in 69.7 % of cases, with increased values of DC potential Xav. There was a moderately pronounced increase in CEM in the frontal, parietal, and right temporal regions of the brain. A rigid reaction was observed during functional tests that simulated physical and emotional stress, indicating a disruption in autonomic regulation and functional tension in the brain. During the functional test that simulated physical stress, there was a predominance of negative CEM responses (excessive, rigid, perverted), compared to those observed during the test that modeled emotional stress. Additionally, there was no recovery of the DC potential Xav. to baseline levels in PHVP, indicating a disruption of physiological adaptation. A reciprocal relationship has been established between the severity of symptoms characteristic of ASD “Trauma event” and the adaptive capacity of brain reactions, as well as the indicator of visual perception. The disorder of adaptive reactions in combatants is associated with the combination of changes in baseline DC potential Xav. during functional tests and the neuropsychological indicator of visual perception, which reflects the vulnerability of the right (subdominant) hemisphere that lead in adaptation and stress response development.

Conflicts of interest

The authors declare no conflicts of interest.

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O.I. Shevchenko formulated the concept, developed the research plan and collected data using appropriate methods. She also wrote and formatted the article and formulated conclusions.

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