

Transcranial electrical stimulation to increase psychophysiological stability, technical and tactical readiness of MMA fighters

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Published online: June 30, 2022

(Accepted for publication June 15, 2022)

DOI:10.7752/jpes.2022.06178

Abstract:

An increase in the psycho-physiological level as well as technical and tactical readiness in martial arts refers to the leading factors allowing an athlete to effectively conduct a bout with an opponent. The study of various means and methods aimed at optimizing these factors is an urgent problem in the sports world. Research aim: to study the effect of transcranial electrical stimulation to improve the psychophysiological stability, technical and tactical readiness of MMA fighters. *Research materials and methods.* The research project was carried out in the pre-competition period with MMA athletes engaged in wrestling clubs in St. Petersburg (Russia) participation. CG and EG groups were formed, each of 10 people aged 18-27. The training structure was the same in both groups (2 times a day with an interval of 6 hours). In EG, for 8 days, the course of transcranial direct current stimulation (tDCS) was used, which consisted of 1 daily session in the afternoon, in the interval of 1-2 hours before training. Some tests were used to study the psycho-physiological status of all athletes: «Distribution of attention», «Memory for numbers», «Information reception», «Stress level» and «Immediate recall test». The state of the athletes' body vegetative balance was assessed by heart rate variability (HRV). With the use of control exercises and analysis of control bouts video recordings, CG and EG athletes' high-stakes testing of the technical and tactical readiness was carried out. *Research results.* At the beginning of the project, the psycho-physical as well as technical and tactical indicators of the athletes in both groups did not significantly differ from each other. At the end of the project, the values of all indicators of psycho-physiological tests and heart rate variability were significantly better for the athletes of the EG than for the athletes of the CG. Conducting a tDCS course in EG athletes affected a significantly greater increase in quantitative and qualitative indicators of the level of technical and tactical readiness of MMA fighters'. *Conclusions.* The use of transcranial electrical stimulation during the annual macrocycle for mixed martial arts athletes in the pre-competition period showed a high efficiency of increasing their technical and tactical readiness and urgent recovery after intensive training activities.

Key Words: MMA fighters, transcranial electrical stimulation, technical readiness, tactical readiness

Introduction

In modern martial arts, there is a steady increase in the intensity of training, competitive and psycho-emotional loads, stressful situations, and an increase in competition between rivals. A constant search for means and methods is required to optimize an athlete's physical and psycho-physiological state (Hendarto et al., 2018; Koshcheyev, Dolbysheva, 2021). The sports specialists' attention is constantly attracted by biomedical recovery methods preventing the effects of intense physical exertion and stress, especially at the stage of pre-competitive and competitive activities and contribute to achieving higher sports results and accelerating the normalization of the psycho-physical state of the athlete's body (Barshak et al., 2021).

One of the factors limiting the sports result is a violation of the athlete's psycho-functional state. To solve this problem, various psychological trainings have been used for a long time, which are not always effective. Pharmacological drugs that may fall under anti-doping sanctions are also used. Therefore, at the present stage of development of sports physiology and biochemistry, it is necessary to search for new effective, safe and approved by the World Anti-Doping Agency (WADA) methods and means affecting the state of the athlete's functional systems. The problem of using biomedical means of recovery in high-performance sports, where

excessively large physical and psycho-emotional loads are noted, is particularly relevant (Sapto Wibowo et al., 2021).

In modern sports medicine, there is increasing interest in the use of the transcranial direct current stimulation (tDCS) method to optimize the work of brain structures producing opioid peptides and neurotransmitters. tDCS is based on changes in the ionic permeability of cell membranes, the state of discreteness of colloids and proteins in cell protoplasm. Researchers have found a versatile positive effect of this method. For example, Lattari et al. (2018), Vargas et al. ((2018), suggest using tDCS to increase athletes' speed and strength abilities, which are especially necessary in sports where this motor quality is required. In this regard, it seems relevant to study this issue among MMA mixed martial arts fighters. It has been proven to increase endurance after using tDCS in athletes (Anges et al., 2019; Avaria et al., 2018). After a responsible competition, a tDCS session leads to a statistically significant reduction in the athlete's recovery time.

The scientific literature presents publications reflecting the results of research works on the tDCS effect on the athletes' psycho-physiological state (Abedanzade et al., 2021). The use of tDCS leads to an increase in the speed of sensorimotor reactions and an improvement in the mental and physical performance of highly qualified athletes (Grosprêtre et al., 2021; Gold, Ciorciari, 2021).

In the work of Luque-Casado et al. (2019), a synergistic effect of the computed tomography and tDCS use was established. This is manifested not only in improving the effectiveness of training, but also in reducing stress and general fatigue, increasing athletic performance and improving sleep. In the study by Weightman et al. (2020), the influence of a set of tDCS and «game bio-management» techniques on the athletes' condition was studied. After the experiment, a significant improvement in vegetative tone was recorded with the predominance of a balanced (sympathetic and parasympathetic) type of control. In addition, athletes experienced a decrease in the level of personal anxiety. Many scientists have determined that the effects of tDCS indirectly affect the processes of «long-term potentiation» and «depression of synapses», which form the basis of psycho-physiological processes (Yavaria et al., 2018). Therefore, transcranial electrical stimulation is a highly effective non-invasive method of influencing the athlete's body, the use of which has been proven by experimental and clinical studies. At the same time, the issues of the influence of tDCS on MMA fighters' psycho-emotional sphere remain insufficiently studied, in particular, the bandwidth of the brain, the speed of switching attention, the level of mental performance, short-term and operational memory, which determine an athlete's performance success. Insufficient preparedness of this psycho-emotional sphere can reduce the effectiveness of martial artists' tactical and technical training. Therefore, it seems relevant and timely to study this issue.

Research aim is to study the effect of transcranial electrical stimulation to increase MMA fighters' psycho-physiological stability as well as technical and tactical readiness.

Material & methods

The research project was carried out in the pre-competition period of the annual training macrocycle with the participation of male MMA athletes aged 18-27 (22.5 ± 0.8) engaged in wrestling clubs in St. Petersburg (Russia). According to the randomized principle, control (CG, $n=10$) and experimental (EG, $n=10$) groups were formed. All MMA athletes had experience in professional and amateur competitive activities. They had no medical contraindications to the use of tDCS (a tendency to convulsions or epileptic seizures, previously occurring infectious lesions of the central nervous system, hypertension, hydrocephalus, acute mental disorders, thyrotoxicosis, atrial fibrillation, the presence of skin lesions at the sites of electrodes, heart pacemakers). Prior to the use of tDCS, all athletes were subjected to an additional examination with mandatory electroencephalography to identify possible contraindications to this procedure, as well as the absence of EEG signs of paroxysmal activity of neurons, which may indicate the presence of adhesions in the brain, manifestations of «acute waves» or «fast-slow wave» complexes.

The training structure was the same in both groups. These were classes 2 times a day with an interval of 6 hours. In the experimental group (EG), a course of transcranial direct current electrical stimulation (tDCS) was used for 8 days, which consisted of 1 daily session in the afternoon, 1-2 hours before training. The transcranial exposure session was conducted using the Neurostim («Нейростим») apparatus and lasted for 30 minutes. Each subject was in the «lying down» position the electrodes were placed on him as follows: the anode – in the anterior prefrontal cortex, the cathode – on the shoulder. Taking into account the feelings of the subject, the current strength was selected individually, within 1-2 mA.

Tests were used to study the athletes' psycho-physiological status of all: «Distribution of attention», «Memory for numbers», «Information reception», «Stress level» and «Immediate recall test», the results of which were evaluated in points (Melnikov et al., 2018). The state of all athletes' body vegetative balance was assessed by heart rate variability (HRV) according to the protocol proposed by Shlyk (2016) using the ESTECK apparatus (USA). The power of the spectrum in the region of low (LF) and high (HF) frequencies was evaluated; the index of vegetative equilibrium (LF/HF); the integral parameter of the presence or absence of a stress state (SI). High-stakes testing of the athletes' technical readiness was conducted according to The Federal standard of sports training for the sport of mixed martial arts (MMA), 2018 and analysis of video recordings of martial artists' control bouts to assess tactical readiness. The indicators of the attack and defense effectiveness, as well as

the overall effectiveness, were calculated. The ratio of successful attempts of specific technical actions and the total number of attempts in % was considered effective. Digital data processing (arithmetic mean and its error, reliability) was carried out using Microsoft Excel 2003 and Statistica 6.1 software material. To compare the share distribution of indicators, the value of χ^2 criterion was determined. The critical value was $\chi^2=5.99$. Statistically significant differences were considered at $\chi^2 > \chi^2$ critical ($p < 0.05$). The conducted examination of athletes does not violate the principles and rules of the organization of biomedical research, which are reflected in the documents of the Helsinki Declaration of 2008.

Results

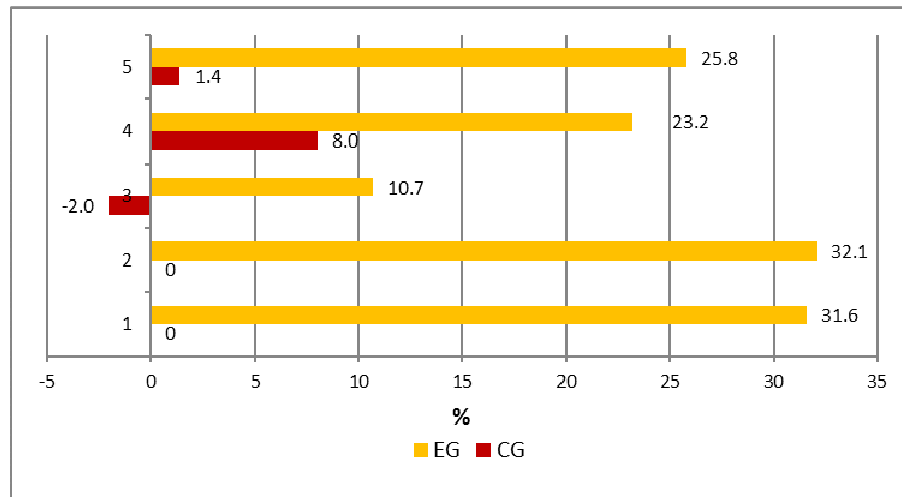
The psycho-physiological state of an athlete's body can have a significant impact on the formation and improvement of the martial artists' technical and tactical readiness. Therefore, it is important to carry out high-stakes testing control of psycho-physiological indicators. The results of the athletes' psycho-physiological status study before and after the research project are presented in Table 1.

Table 1. The results of the athletes' psycho-physiological high-stakes testing control assessment (points, $M \pm m$)

No	Test	CG (n=10)		EG (n=10)	
		At the beginning of the project	At the end of the project	At the beginning of the project	At the end of the project
Psycho-physiological indicators					
1	Distribution of attention	13.5±0.2	13.5±0.2	13.2±0.1	17.3±0.2*
2	Memory for numbers	8.3±0.4	8.3±0.4	8.4±0.4	11.1±0.3*
3	Information reception	30.0±0.3	29.4±0.3	29.8±0.5	33.0±0.6*
4	Stress level	1.62±0.1	1.75±0.06*	1.68±0.1	1.29±0.2*
5	Immediate recall test	28.0±1.0	28.4±0.3	28.3±1.1	35.6±1.0*

Note.* the indicators difference is significant ($p < 0,05$)

At the beginning of the research project, there were no significant differences in the values of the psycho-physiological tests indicators between the athletes of CG and EG, $p > 0.05$. After the completion of the study in CG, the values of test No 4 indicators significantly worsened. In EG athletes, the values of all indicators of psycho-physiological tests are significantly better than at the beginning of the study, $p < 0.05$. The increase in the values of psycho-physiological tests indicators in EG and CG athletes is shown in Figure 1.



Note. Vertically, the numbers 1-5 are the number of tests

Fig. 1. The increase in the psycho-physiological tests indicators values in athletes CG and EG at the end of the experiment

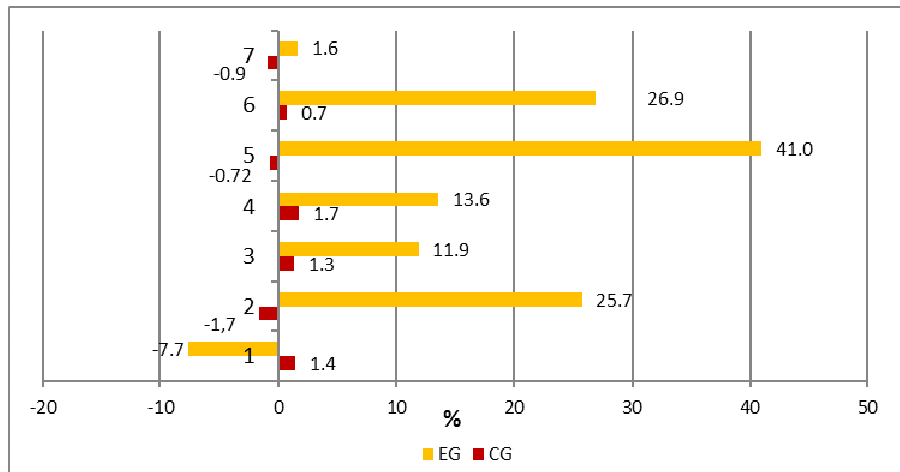
At the end of the research project, EG athletes have a significant increase in the values of all psycho-physiological tests. In CG athletes, a slight increase in values was found in two of the five psycho-physiological tests (No 4 and No 5). In two tests (No 1 and No 2), no increase was found, in one test (No 3), a deterioration in the value of the indicator was recorded. At the beginning and end of the project, we conducted a study of the heart rate variability (HRV) of athletes in both groups, Table 2.

Table 2. The results of the CG and EG athletes' HRV high-stakes testing control indicators (M±m)

No	HRV indicators	At the beginning of the project		At the end of the project	
		CG	EG	CG	EG
1	Heart rate (HR), bpm	67.2±2.6	68.6±2.7	68.2±2.8	63.3±2.6*
2	HF – high frequency waves, ms ²	1052.0±26.8	1087.0±25.7	1034.0±25.9	1367.0±31.3*
3	LF - low frequency waves, ms ²	810.0±17.8	802.0±18.7	821.0±18.9	898.0± 19.7*
4	VLF – very low frequency waves, ms ²	1690.0±38.9	1700.0±40.2	1720.0±42.8	1931.0±48.7*
5	LF/HF vegetative equilibrium, RU	1.38±0.23	1.39±0.27	1.37±0.17	1.96±0.35*
6	SI stress-index, RU	27.8±2.2	28.2±2.4	28.0±2.0	35.8±2.9*
7	RRNN, ms	768.0±17.7	772.0±18.9	761.0±17.3	784.0±19.8

Note.* the indicators difference is significant (p< 0,05)

After the completion of the project, it was found that the values of indicators (No 2-6) significantly increased in EG athletes, compared with the values of these indicators in CG fighters. The design of the increase in the HRV values indicators for athletes of the CG and EG at the end of the project is shown in Figure 2.



Note. Vertically, the numbers 1-7 are the number of tests

Fig. 2. Increase in heart rate variability indicators by the end of the project

By the end of the project, the athletes of the experimental group had a greater increase in the HRV indicators values (No 2-7) than the fighters of the control group. The heart rate of EG athletes significantly decreased by 7.7%, this fact indicates an increase in the reserve capabilities of their cardiovascular system after applying the tDCS course. The use of tDCS in EG athletes affected the quantitative and qualitative results of the MMA fighters' technical and tactical readiness level, Table 3.

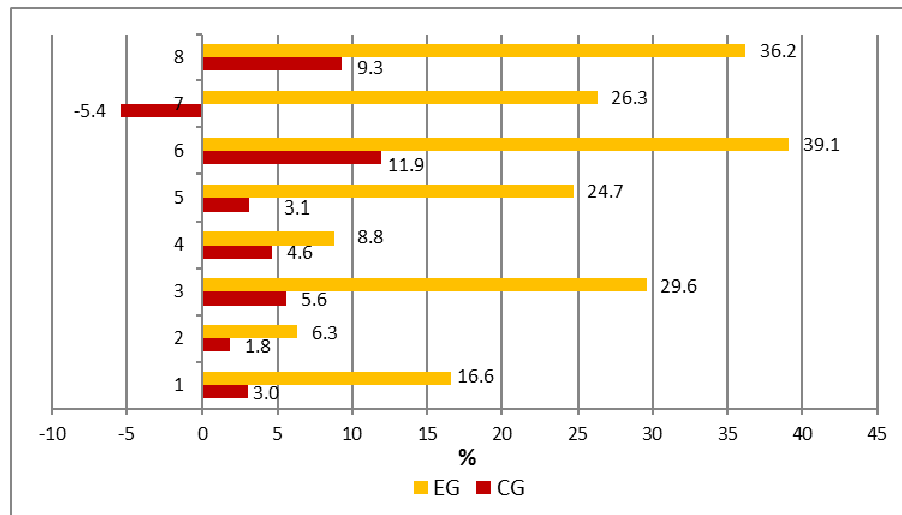
Table 3. High-stakes control testing indicators of the CG and EG athletes' technical and tactical readiness

No	Test	CG (n=10)		EG (n=10)	
		At the beginning of the project	At the end of the project	At the beginning of the project	At the end of the project
Technical indicators (M±m)					
1	Straight blows with two hands for 10 seconds, number of times	26.4±1.2	27.2±1.3	25.2±1.1	29.4±1.4*
2	Straight blows with two hands for 1 minute, number of times	61.7±4.5	62.8±4.6	61.7±4.4	65.6±4.8
3	Circular kicks inwards with the far leg for 10 seconds, number of times	12.5±0.8	13.2±1.0	12.5±0.9	16.2±1.1*
4	Circular kicks inwards with the far leg for 1 minute, number of times	39.4±2.2	41.2±2.4	40.6±2.4	44.2±2.9
5	10 hip throws, s	19.4±1.3	20.0±1.5	19.4±1.1	24.2 ±1.9*
Tactical indicators, %					
6	Attack effectiveness	42.0	47.0	41.0	57.0*
7	Defence effectiveness	55.0	52.0	57.0	72.0*
8	General effectiveness	97.0	106.0	94.0	128.0*

Note.* the indicators difference is significant (p< 0,05)

At the beginning of the research project, the values of the technical and tactical indicators of the CG and EG fighters did not differ from each other, $p > 0.05$. The effectiveness of attacking actions of the fighters in both groups averaged 41.5%, the effectiveness of protection was above average (56.5%), the overall effectiveness was less than 100%. This indicates an insufficient level of all athletes' tactical readiness.

At the end of the project (Table 3), the CG athletes did not have significant changes in the values of the technical and tactical readiness testing indicators. The EG fighters registered a significant improvement in the values of indicators in tests # 1,3,5,6,7,8 $p < 0.05$. This fact indicates the effectiveness of using the tDCS method to increase the EG athletes' technical and tactical readiness. The increase in the indicators of technical and tactical readiness of athletes in both groups at the end of the project is shown in Figure 3.



Note. Vertically, the numbers 1-8 are the number of tests

Fig. 3. The increase in the CG and EG athletes' technical and tactical readiness values at the end of the project

An increase in the values of the EG athletes' performance indicators of technical and tactical readiness correlates with an increase in the values of the psycho-physiological sphere and the reserve capabilities of the athletes' body indicators. We believe that the tDCS method produces high interference immunity of MMA fighters and forms an optimal structure for conducting a bout.

Dicussion

In sports practice, it is very important and relevant to search for effective psycho-physiological means and methods of highly qualified athletes' recovery in modern conditions of a constant increase in the volume and intensity of physical and psycho-emotional loads in training and competitive activities. One of these methods is transcranial stimulation (tDCS) of the athlete's cerebral cortex with a constant electric current of low power. Issues related to the study of the influence of tDCS on the fighters' psycho-emotional sphere, motor and technical and tactical qualities development for optimizing sports activities remain relevant (Barshak et al., 2021). The issues of using tDCS in qualified athletes' engaged in MMA pre-competitive training have not been sufficiently studied.

The results obtained by us using transcranial stimulation of the cerebral cortex of MMA fighters indicate a positive response of their body from the psycho-emotional sphere. At the end of the project, the athletes of the experimental group examined by us had significantly higher test scores for assessing the distribution of attention, the volume and accuracy of reproduced information, the sense of distance perception as well as the technical and tactical features of the opponent's behavior, compared with the results of testing athletes in the control group.

After the tDCS course, EG athletes experienced an increase in the level of perception and understanding of information and the level of tactical actions efficiency that are most favorable for fighters in a bout. A significant decrease in the stress test index in EG athletes is important for the fighters' psycho-physical state, compared with CG ones, in whom testing has established an increase in stress levels. Kaminski et al. (2021) proved the effectiveness of the combined effects of tDCS and laserophoresis with serotonin for the psycho-emotional stress prevention. After impact to such exposure, athletes had a significant decrease in negative stress symptoms by 17% (Wertheim et al., 2020).

An important subject of an athlete's psycho-physiological sphere testing is his operative memory. At the beginning of our project, CG and EG athletes registered a low level of immediate recall (28.0 ± 1.0 and 28.3 ± 1.1

points, respectively), which can lead to an incorrect assessment of the current situation in the ring by the fighter during the bout. The results of the final testing showed that the results did not change in the control group. In the experimental group, the number of points increased by 27.1% ($p < 0.05$). The results of the psycho-physiological study of athletes obtained by us are consistent with the data obtained by Parasuraman, McKinley (2014) in the study of people's cognitive abilities. The tDCS method affects the functional state of the brain by gradually reducing slow- and fast-wave activity and improving the alpha activity of nerve structures (Grosprêtre et al., 2021; Gold, J., Ciorciari, 2021; Hung et al., 2021). According to Da Silva Machado et al. (2021), such brain activity may contribute to achieving higher sports results in the future.

The use of tDCS after traditional physical activity reduces the Robinson index and leads to an acceleration of recovery processes in skiers' body. If the parasympathetic part of the athlete's nervous system is active when exposed to pulsed currents, then there is a decrease in the duration of the recovery period due to changes in the heart rate regulation. In athletes with high activity of the sympathetic department, tDCS causes tension of regulatory mechanisms (Kudrya, Shigina, 2019). Higher values of HPV indicators in EG athletes (compared to CG) established by us after completing the tDCS course indicate economical heart work and an increase in the reserve capabilities of the EG athletes' body associated with an increase in parasympathetic heart activity and a slowdown in heart rate. This is consistent with the results of Kudrya, Shigina (2019).

The literature provides data indicating an increase in the speed and effectiveness of human motor skills training using the tDCS method (Naros et al., 2016) and athletes (Hung et al., 2021). Our experimental data are consistent with the studies of these authors on the greater effectiveness of motor learning in humans. We have registered higher results of testing technical readiness after using the tDCS course in the EG athletes, compared with the CG ones.

Conclusions

One of the main factors influencing MMA fighters' performance success at competitions is the implementation of a technical and tactical plan of the fight, readiness for unforeseen stress situations and perception of the opponent's fighting style. As a result of our research project, it was found that the transcranial electrical stimulation method statistically significantly improves the athlete's operational memory, the volume and accuracy of his visual memory, the level of perception and distribution of information coming from outside, which is important in the technical and tactical readiness of qualified athletes.

The results of the experiment showed that after applying the tDCS course, the recovery process of the athlete's body after physical exertion accelerated. This method had a positive effect on the variability of the athletes' heart rate. The activity of the autonomous heart regulation circuit with a parasympathetic innervation predominance has increased, which increases the tolerance of the cardiovascular system to physical work and the adaptive reserves of the martial artists' body.

The use of tDCS in the pre-competition period of the annual training macrocycle makes it possible to increase the psycho-physical indicators, the technical and tactical readiness of the athlete and the effectiveness of attack, defense and techniques performance level indicators.

The high efficiency, ease of use, mobility, and relatively low financial costs of the transcranial electrical stimulation method allow recommending it for use in the pre-competition period of training athletes to achieve success in sports activities.

Conflicts of interest. The authors declare no conflict of interest

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