THE EFFECT OF A SINGLE PROCEDURE OF COMBINED MICROPOLARIZATION ON AUTONOMIC REGULATION AND SENSORIMOTOR REACTIONS

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Micropolarization was already proved an effective method for restoring impaired brain functions and improving intracerebral processes in the absence of impairments. Combining stimulation methods is a promising approach: a combination of electrode positioning methods can increase the efficacy of the procedures and find application in various fields, from sports through machinery operation to support of operatives of the Ministry of Emergency Situations, etc. This study aimed to assess the effect of a single combined micropolarization procedure on the functional state of the autonomic nervous system and sensorimotor reactions of conventionally healthy individuals. It involved 31 people and relied on the methods enabling evaluation of sensorimotor reactions, cardiorhythmography with spectral analysis of heart rate variability and pupillary reflexes assessment. Volunteers underwent the combined micropolarization procedure once, the duration of the procedure was 40 minutes. The most effective combinations were transspinal plus transcranial micropolarization with positioning in the region of premotor cortex (short-term shift of the autonomic balance towards parasympathetic influence by 48.7%; optimization of the pupil recovery function by 26.4%; increase in interference immunity by 32.2%) and "solar" plus transcranial micropolarization in the area of the temporal zone of cerebral cortex (15.8% increase of the orthostatic test transition period ratio; 6.2% deceleration of the visual-motor reaction).

Keywords: transcranial micropolarization, functional state, autonomic regulation, sensorimotor reactions, transcranial stimulation, direct current

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Compliance with ethical standards: the study was approved by the Ethics Committee of the Research Institute of Hygiene, Occupational Pathology and Human Ecology of FMBA of Russia (minutes #2 of February 28, 2019). All volunteers signed the informed written consent to participation in the study.

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ВЛИЯНИЕ ОДНОКРАТНОЙ ПРОЦЕДУРЫ КОМБИНИРОВАННОЙ МИКРОПОЛЯРИЗАЦИИ НА ВЕГЕТАТИВНУЮ РЕГУЛЯЦИЮ И СЕНСОРНО-МОТОРНЫЕ РЕАКЦИИ

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Метод микрополяризации уже показал свою эффективность для восстановления нарушенных мозговых функций, а также для улучшения внутримозговых процессов в норме. Перспективным направлением представляется комбинирование методов стимуляции, поскольку сочетание методов позиционирования электродов может повысить результативность процедур и найти применение в различных сферах деятельности: сопровождении операторов, спортсменов, сотрудников МЧС и др. Целью исследования было оценить влияние однократной комбинированной микрополяризации на функциональное состояние вегетативной нервной системы и сенсорно-моторные реакции условно здоровых лиц. В исследовании с участием 31 человека использовали методики для оценки сенсорно-моторных реакций, кардиоритмографии со спектральным анализом вариабельности сердечного ритма, проводили оценку зрачковых рефлексов. Процедуру комбинированной микрополяризации добровольцы проходили однократно, в течение 40 мин. Наиболее эффективными оказались схемы комбинации трансспинальной и транскраниальной микрополяризации с позиционированием в области премоторной зоны коры головного мозга (краткосрочное смещение вегетативного баланса в сторону парасимпатического влияния — на 48,7%; оптимизация функции восстановления зрачка — на 26,4%; увеличение помехоустойчивости — на 32,2%), и комбинации «солярной» и транскраниальной микрополяризации в области проекции височной зоны коры головного мозга (увеличение коэффициента переходного периода в ортостатической пробе — на 15,8%; замедления зрительно-моторной реакции — на 6,2%).

Ключевые слова: транскраниальная микрополяризация, функциональное состояние, вегетативная регуляция, сенсорно-моторные реакции, транскраниальная стимуляция, постоянный ток

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Recent studies have shown that micropolarization is effective in both functional restoration following pathological processes [1, 2] and functional improvement when intracerebral processes are normal [3–5]. Micropolarization was demonstrated [5–7] to reduce the severity of manifestations of the chronic fatigue syndrome; normalize autonomic regulation processes (vascular tone, blood pressure, stimulation of humoral and cellular immunity); normalize psychophysiological state, produce anti-stress and antidepressant effects, alleviate fatigue, improve performance etc.

Methods that combine cerebral cortex transcranial micropolarization and additional spinal nerves transspinal stimulation (both direct current and magnetic impulses) seem to show promise [6, 7].

Transspinal micropolarization is a method for treatment of cerebral functional disorders associated with vascular tone regulation [7]. Transspinal micropolarization optimizes the parasympathetic effect on the heart rate by engaging the neural pathway for autonomic nervous system (ANS) activation [6].

Earlier studies [8, 9] suggested the option of "solar" micropolarization, which implies acting on the solar plexus area where there is a large cluster of autonomic neurons that receive up to 90% of signals from the metasympathetic nervous system of the abdominal region and are closely connected with the vagus and sympathetic nerves. The neural ganglia in the solar plexus region play an important regulatory role on the part of the ANS.

Thus, in order to improve the methodology supporting practical use of micropolarization, it seems important to evaluate and compare the effects of various approaches to combined micropolarization.

The purpose of this study was to assess the effect of a single combined micropolarization procedure on the functional state of the ANS and sensorimotor reactions of conventionally healthy individuals.

METHODS

The study involved 31 volunteers, students of the St. Petersburg Medical and Social Institute (20 people) and other educational establishment (11 people), aged 20–25 years, 17 male and 14 female. The inclusion criteria were: signed voluntary informed consent; permission to participate given by a neurologist and a physician following relevant examinations. The exclusion criteria were: acute mental disorders, convulsive conditions, epilepsy; trauma and brain tumors; infectious lesions of the central nervous system (CNS); hypertension or hypotension, hydrocephalus; thyrotoxicosis; atrial fibrillation, skin damage at the electrode sites; implanted pacemakers; a history of clinically significant allergic reactions, alcoholism, drug addiction.

The assessment of the state of the nervous system relied on the following methods: 1) cardiorhythmography (GHR) with spectral analysis of heart rate variability (VNS Micro hardware and software system, Neurosoft; Russia); 2) Pupillometry test for assessment of pupillary reflexes (KSRZRts-01 digital pupillometric complex; Research Institute of Hygiene, Occupational Pathology and Human Ecology of the FMBA; Russia); 3) test for evaluation of spatio-temporal reactions — RDO (reaction to a moving object), PZMR (simple visual-motor response test), interference immunity.

The key criteria for assessment of autonomic reactions to a single micropolarization procedure were the classic heart rate variability indications: frequency range in high, medium and low regions, their interrelation, orthostatic test index and pupillary reaction indicators.

The time of pupil constriction and dilatation reflects the functions of cholinergic (parasympathetic) and adrenergic (sympathetic) constituents of the pupil's dual innervation. The speed of pupil constriction and dilation reflects the activity of parasympathetic and sympathetic components when the pupil constricts or dilutes, and the amplitude of constriction indicates vegetative activity in the pupillomotor system. If the difference between initial and final diameters of the pupil is greater than 0.45 mm, the pupil's restoration is abnormal, which is associated with the predominance of parasympathetic activity, a sign of fatigue. To quantify the pupillary reaction, we processed the pupillogram (automated mathematical processing) factoring in the generally accepted pupillometric indicators: the pupil diameter before the light stimulus; final diameter of the pupil; time of the latent period of pupillary reaction; time of pupil constriction (parasympathetic phase); time of pupil dilation (sympathetic phase); average rate of pupil constriction; average rate of pupil dilation; amplitude of the pupil constriction. Pupil reaction is a reliable indicator of the level of attention [10].

The RDO (Reaction to a moving object), PZMR (simple visual-motor response) and Attention and Interference Immunity tests allowed evaluating the speed and quality characteristics of sensory and motor processes and indirectly estimate the balance of mental processes in the context of the specifics of higher nervous activity (since the response time depends on the properties of excitation and inhibition processes and the person's functional state, the level of fatigue in particular).

After testing, the participants underwent 40 minutes of the combined micropolarization procedure, followed by another testing session.

The combination included transspinal, transcranial and "solar" micropolarization in varying patterns.

For transspinal micropolarization, we used 200 μA direct current delivered through the cutaneous electrodes

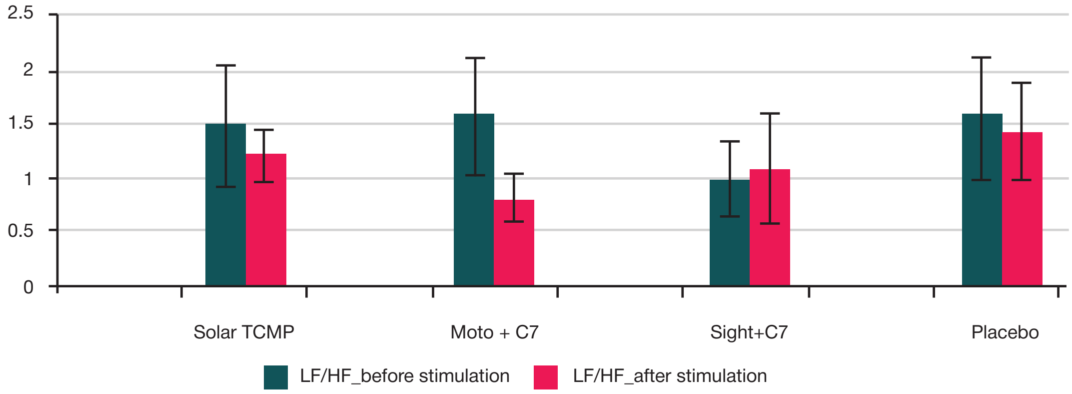

Fig. 1. Change in the LF/HF ratio after the micropolarization procedure. * — statistically significant changes ($p < 0.05$; Wilcoxon test)

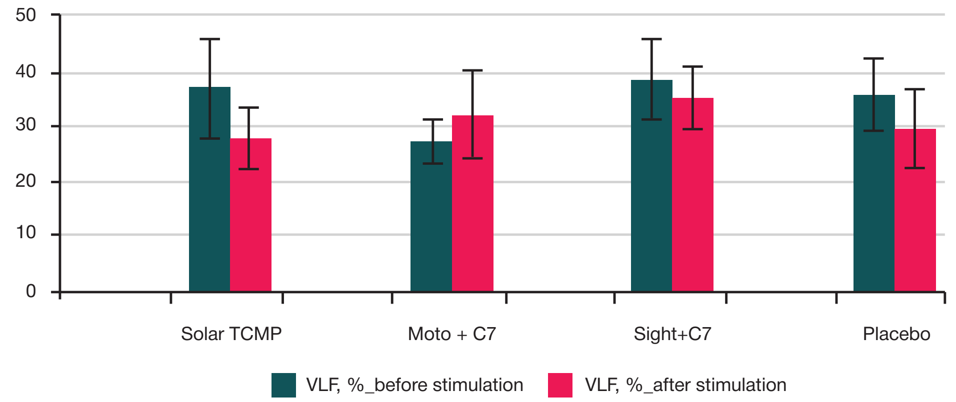

Fig. 2. Changes in the VLF component of the heart rate range after the micropolarization procedure

applied above the spinal canal where spinal nerves exit it; anode was placed laterally from the spinous process of the seventh cervical vertebra (C7), cathode — contralateral to the lumbosacral zone at the level of spinous processes (L5–S1).

For transcranial micropolarization, we used 200 μA direct current delivered to the primary visual cortex plane (anode — O1 of the left hemisphere, cathode — contralateral lumbosacral zone at the level of spinous processes L5-S1), primary motor cortex plane (anode — M1, cathode — right shoulder area), temporal cortex plane (anode — T3, cathode — the area of the right shoulder).

"Solar" micropolarization procedure employed 200 μA direct current delivered to the solar plexus area through an anode just below the umbilical region and a cathode on the right shoulder.

The sample was divided into four groups.

– Group 1 (8 people), single procedure, combination of transspinal and transcranial micropolarization, the latter applied in the primary motor cortex area. The pattern of application and the group were called "Moto + C7."

– Group 2 (8 people), single procedure, combination of transspinal and transcranial micropolarization, the latter applied in the primary visual cortex area). This pattern of application (and the group) was named "Sight + C7."

– Group 3 (8 people), single procedure, transcranial and "solar" micropolarization, the former applied in the temporal zone, the latter — above autonomic ganglia of the solar plexus. This pattern, together with the group, was dubbed "Solar TCMP."

– Group 4 (7 people), placebo: the participants had the electrodes applied as in the "Moto + C7" pattern, but there was no current running through them throughout the procedure. This group was called "Placebo."

RESULTS

Figures 1–4 show the average values of the spectral analysis of heart rate variability for all four groups before and after the single micropolarization procedure.

We have registered significant ($p < 0.05$; Wilcoxon test) changes in the LF/HF indicator (Fig. 1). This indicator was detected decreasing by 48.7% from the baseline level in the Group 1, where the current was directed at the premotor cortex area ("Moto + C7"). Relative to the placebo group, the decrease in LF/HF was 43.5%. Against the comparison group, no significant changes in the dynamics of the indicator were detected. The values of this indicator tended to decrease in groups 2 and 3, too, where the micropolarization procedure was of the combined type with different electrode application spots.

We identified no significant differences ($p > 0.05$; Wilcoxon test) between all groups, "Placebo" included, in the values of the VLF indicator (the lowest frequency range of the heart rate variability) (Fig. 2). This indicator shows the level of neurohumoral activity.

The total spectral power of the heart rate TP reflects the total contribution of all assessed components to the regulation of the ANS. Same as for the previous indicator, we identified no significant differences between the groups for this one, either (Fig. 3, $p > 0.05$).

The K30:15 ratio increased by 15.8% in Group 3, "Solar TCMP"; the change is significant ($p < 0.05$; Wilcoxon test) (Fig. 4). It should be noted that this is the only group where we detected a significant change in this indicator. Relative to the placebo group, the increase was 12.8%.

Figures 5–7 show the values of the integral characteristics of the central nervous system before and after the single micropolarization procedure through all the four groups.

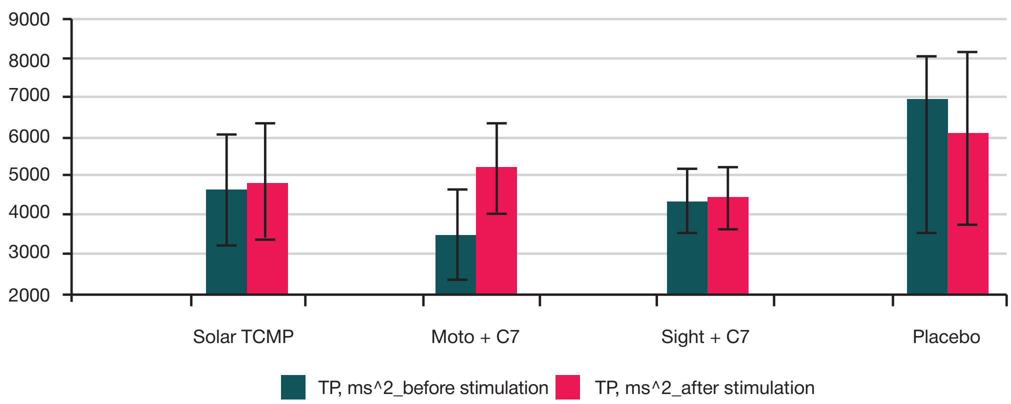

Fig. 3. Change in the total spectral power (TP) after the micropolarization procedure

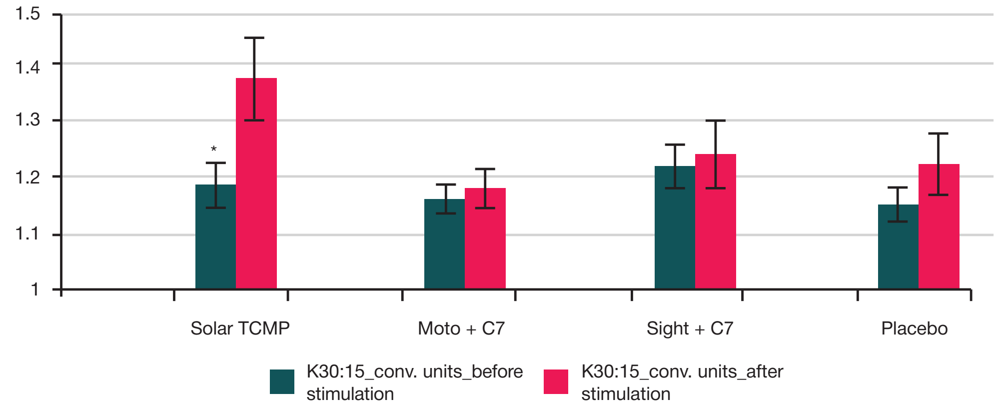

Fig. 4. Change in the K30:15 ratio after the micropolarization procedure. * — statistically significant changes ($p < 0.05$; Wilcoxon test)

We identified significant ($p < 0.05$) changes in the mean reaction time with the simple visual-motor response test (Fig. 5). In the "Solar TCMP" group, this indicator has grown by 6.2% relative to the baseline initial level.

There were identified no significant differences in the "balance of mental processes" indicator registered with the RDO (reaction to a moving object) test ($p > 0.05$).

The interference resistance value significantly increased by 32.2% ($p < 0.05$; Wilcoxon test) in group 1 ("Moto + C7") after the procedure. The participants in this group had an increased level of attention and interference immunity (Fig. 7). Relative to the placebo group, the increase was 12.8%.

Pupillometry done after the micropolarization procedure allowed identifying a small number of statistically significant differences in the changing values of indicators (see Table). In the group where electrodes were applied to the solar ganglia and temporal zones, the pupil diameter decreased by 26.4% from the initial to the final states, which is significant. In absolute figures, the diameter value in this group was more than 0.45 mm, which confirms the insufficient recovery of the pupil.

The analysis of pupillometry indicator values before and after the "Sight + C7" pattern procedure reveals specific peculiarities of the pupil dilation time alteration, one of which is the slight yet significant (2.2%) shortening of the dilation time that characterizes activation of parasympathetic regulation mechanisms.

DISCUSSION

The combination of anodic transcranial stimulation with the electrode on the primary motor cortex plane (anode — M1, cathode — right shoulder) and transspinal stimulation (anode — C7, cathode — contralateral to the lumbosacral zone at the level of the spinous processes L5-S1) had a positive effect on autonomic regulation: the parasympathetic and sympathetic influence were optimized (LF/HF ratio was reduced), which, presumably, improved attention focusing (increased interference immunity).

The low-frequency and high-frequency parts of the heart rate variability range reflect the activity of the sympathetic and parasympathetic divisions of the ANS. The LF/HF ratio characterizes the vegetative balance and gives an idea of the involvement of the central link of regulation. The mentioned reduction of this ratio can be interpreted as signaling of the growing activity of the parasympathetic part of the ANS.

Pupil diameter monitoring and K30:15 value obtained from the orthostatic test allowed discovering activation of the recovery processes in response to the combination of transcranial stimulation at the temporal zone (anode — T3, cathode — right shoulder area) and stimulation above the solar plexus.

The K30:15 ratio characterizes the speed of optimization of the person's condition when he/she stands up from the supine position (orthostatic test). The registered dynamics allow assuming that a single micropolarization procedure improves general condition of the body.

The pupil function has links to various parts of the central and autonomic nervous systems, which allows considering it a sensitive probe capable of reporting the functional state of a person [11]. Autonomic nervous system, which enables adaptation of the body both to various environmental influences and to high physical loads, is one of the first bodily systems to respond to such influences/loads. In healthy people,

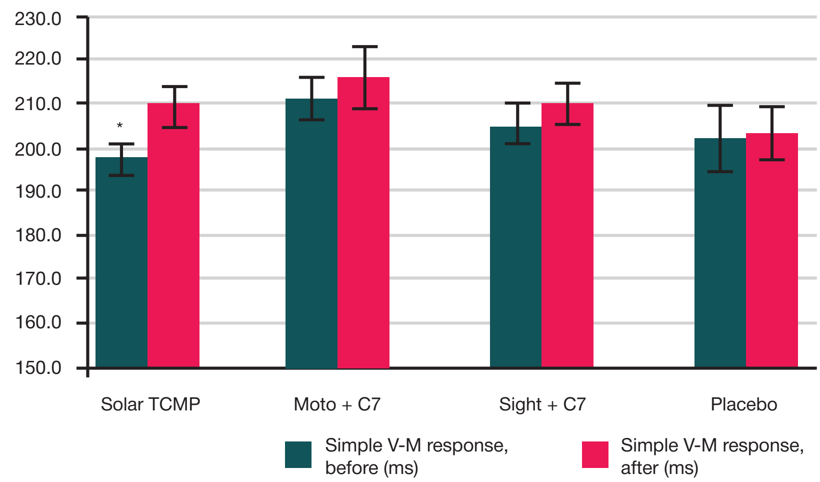

Fig. 5. Change in the mean reaction time (simple visual-motor response test) after the micropolarization procedure. * — statistically significant changes ($p < 0.05$; Wilcoxon test)

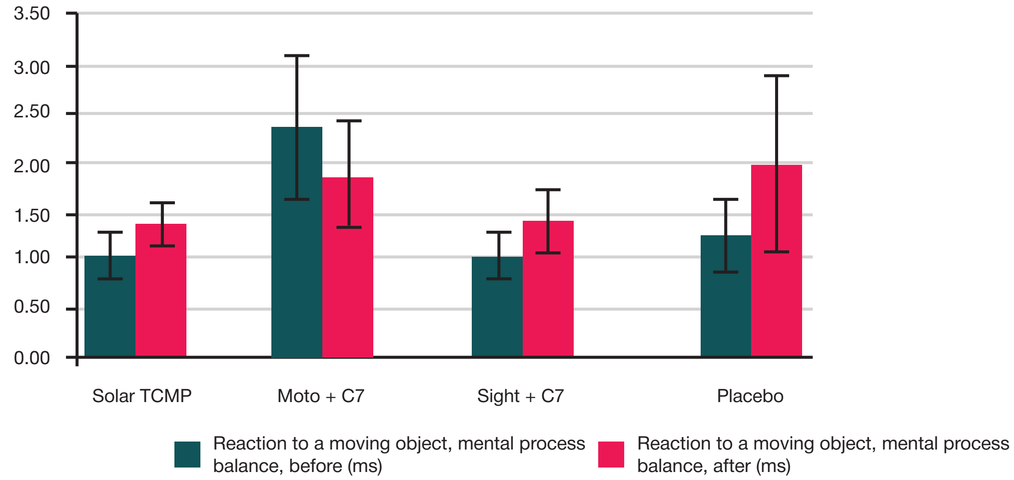

Fig. 6. Change in the balance of inhibition and excitation (RDO test) after the micropolarization procedure

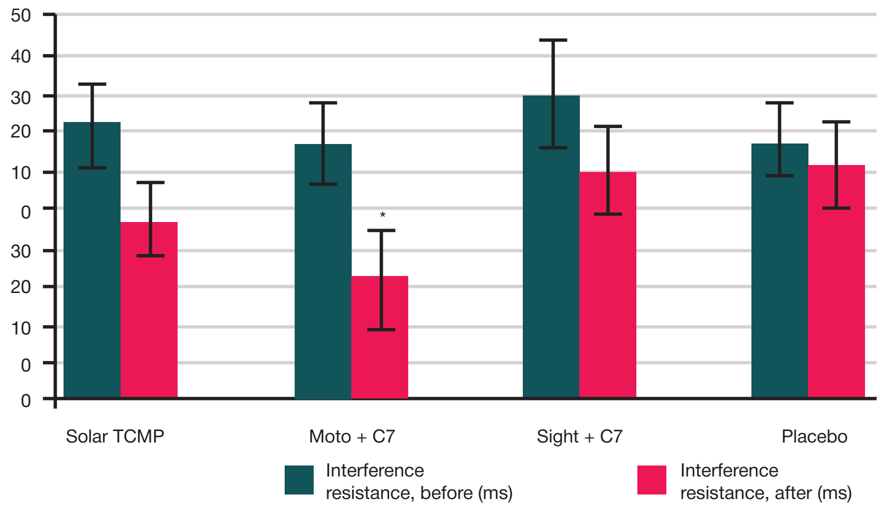

Fig. 7. Change of interference immunity values after the micropolarization procedure. * — statistically significant changes ($p < 0.05$; Wilcoxon test)

pupil function largely depends on the state of the ANS, which adds to the importance of its testing because the fatigue-related impairment of this function may manifest before other symptoms signaling of the CNS and ANS fatigue and deterioration of the adaptive capabilities. A smaller difference between the initial and final diameters of the pupil indicates optimization of action of the sympathetic and parasympathetic divisions of the ANS. The results of this study are consistent with the data reported by other authors who researched the pupillomotor system reaction in people undergoing adjustment procedures [12, 13].

As for the modulation of sensorimotor reactions, we registered activation of the inhibition processes, which is confirmed by the increased visual-motor response time. The changes of the mean reaction time detected with the simple visual-motor response test can be interpreted as signaling of the growing inhibitory influences. The effect may come from the

Table. Dynamics of pupillometry indicator values after the micropolarization procedure

Group	Solar TCMP		Moto + C7		Sight + C7		Placebo	
	Before stimulation	After stimulation	Before stimulation	After stimulation	Before stimulation	After stimulation	Before stimulation	After stimulation
Di	6,26 ± 0,30	6,03 ± 0,28	5,97 ± 0,32	6,18 ± 0,17	5,52 ± 0,41	5,75 ± 0,40	5,82 ± 0,30	5,94 ± 0,27
Tl	0,28 ± 0,01	0,28 ± 0,01	0,28 ± 0,01	0,29 ± 0,01	0,28 ± 0,01	0,28 ± 0,01	0,28 ± 0,01	0,27 ± 0,01
Ac	1,67 ± 0,12	1,64 ± 0,08	1,57 ± 0,10	1,61 ± 0,07	1,60 ± 0,14	1,66 ± 0,11	1,61 ± 0,09	1,61 ± 0,12
Tc	0,51 ± 0,03	0,53 ± 0,02	0,46 ± 0,03	0,48 ± 0,02	0,46 ± 0,02	0,51 ± 0,02	0,48 ± 0,03	0,51 ± 0,03
Td	2,21 ± 0,03	2,20 ± 0,02	2,26 ± 0,03	2,23 ± 0,02	2,26 ± 0,02	2,21 ± 0,02*	2,24 ± 0,03	2,22 ± 0,03
Vc	3,28 ± 0,17	3,14 ± 0,16	3,46 ± 0,14	3,38 ± 0,18	3,46 ± 0,23	3,24 ± 0,14	3,40 ± 0,17	3,20 ± 0,16
Vd	0,76 ± 0,06	0,75 ± 0,04	0,67 ± 0,07	0,72 ± 0,03	0,72 ± 0,06	0,83 ± 0,10	0,72 ± 0,05	0,73 ± 0,06
Df	5,73 ± 0,29	5,63 ± 0,26	5,71 ± 0,31	5,75 ± 0,14	5,19 ± 0,35	5,39 ± 0,33	5,31 ± 0,32	5,42 ± 0,29
Di-Df	0,53 ± 0,06	0,39 ± 0,06*	0,26 ± 0,05	0,44 ± 0,07	0,33 ± 0,08	0,36 ± 0,13	0,51 ± 0,12	0,52 ± 0,11

Note: Di (mm) — initial pupil diameter before the light stimulus; Df (mm) — final pupil diameter; Tl (s) — time of the latent period of pupillary reaction; Tc (s) — pupil constriction time (parasympathetic phase); Td (s) — pupil dilation time (sympathetic phase); Vc (mm/s) - average pupil constriction speed; Vd (mm/s) — average pupil dilation speed; Ac (mm) — amplitude of pupil constriction. Pupil reaction is a reliable indicator of the level of attention; * — value is significant with respect to background ($p < 0.05$; Wilcoxon test).

increased contribution of parasympathetic part of the ANS to the regulation of the functional state.

There were no significant effects detected for the combination of transcranial stimulation in the primary visual cortex plane (anode — O1, cathode — L5-S1) and transspinal stimulation (anode — C7, cathode — L5-S1).

The revealed effects of micropolarization pattern combinations enable further improvement of the methods of micropolarization procedures. The tested patterns may find practical application in professional sports. For example, optimization of the autonomic regulation processes is of paramount importance for athletes in biathlon, where it is extremely important to switch between dynamic and static physical loads in an optimal way.

CONCLUSIONS

This study assessed the effect of a single combined micropolarization procedure on the functional state of the ANS and sensorimotor reactions of conventionally healthy individuals. We tested three electrode positioning patterns. The results of the study show that the considered combinations of patterns produce different effects. The most effective combinations were: 1) transspinal plus transcranial micropolarization with electrode positioning in the region of premotor cortex, which triggered a short-term shift of the autonomic balance towards parasympathetic influence (by the LF/HF ratio) by 48.7%; optimization of the pupil recovery function by 26.4%; increase in interference immunity by 32.2%; 2) "solar" plus transcranial micropolarization in the area of the temporal zone of cerebral cortex, which increased the K30:15 ratio by 15.8% (discovered with an orthostatic test) and the visual-motor reaction deceleration by 6.2%. Further investigation of the characteristics of exposure time and current strength in the context of combined micropolarization procedures seems promising; such studies may be aimed at selecting the more effective stimulation modes.

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