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Features of the Brain Electrical Activity of Athletes-Fighters in Comparison with Non-athletes

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Abstract The study of the neural mechanisms underlying sports performance was aimed at studying the characteristics of the brain electrical activity of athletes-fighters in comparison with non-athletes. Thirty young men of 19.97±0.23 years old (with the height of 179.82±2.15 cm and the body weight of 78.61±1.68 kg) engaged in wrestling (with the qualification "Master of Sports"), and thirty young men of 19.25±0.18 years old (with the height of 178.35±2.25 cm and the body weight of 77.93±1.45 kg), not involved in sports, analyzed the frequency ranges delta, theta, alpha, beta 1 and beta 2 rhythms of electroencephalography (EEG) at rest in three epochs: the first epoch with closed eyes, the second epoch with open eyes, and the third epoch with closed eyes. The results of the study showed that in wrestlers, the neural advantage over non-athletes is expressed only in a decrease in alpha rhythm fluctuations: with closed eyes in the left hemisphere by 17.07% ($p<0.05$), and in the right hemisphere by 17.35% ($p<0.05$). With open eyes, the difference was 21.17% ($p<0.01$) in the left hemisphere and 19.27% ($p<0.05$) in the right hemisphere, which indicates a lower cortical activity of the brain of athletes. At the same time, the coefficient of reactivity (CR) of the alpha rhythm during the receipt of visual information in athletes in the left hemisphere is 20% higher, and when it is interrupted, it is 18% lower than in non-athletes. In the right hemisphere, CR does not differ. We concluded that wrestlers recruited fewer neural resources without compromising performance, supporting the hypothesis of neuronal flexibility in the brains of athletes compared to non-athletes.

Keywords Electroencephalography (EEG), Brain Electrical Activity, Wrestlers, Athletes, Non-athletes, Central Nervous System

1. Introduction

The bioelectrical activity of the brain of athletes today is increasingly attracting the attention of neurobiologists, since elite athletes are an ideal model for studying neural adaptations associated with intense training and the specifics of motor activity [1]. Today, success in wrestling depends not only on excellent physical shape, but also on emotional and psychological stability, cognitive endurance, individual and personal qualities, character of an athlete, and, in general, on the level of cognitive and psychological preparedness [2].

Among modern neuroimaging methods, such as functional magnetic resonance imaging, EEG, near infrared topography and spectroscopy, EEG is the most widely used method due to its non-invasive nature and high temporal resolution [3]. It is worth saying that EEG is one of the oldest methods for assessing the relation between the brain and behavior, and many researchers agree that it provides insight into the neural mechanisms that underlie sports performance [3,4].

Over the past ten years, two extensive narrative reviews have been available on the study of EEG profiles of athletes [3,4]. However, there are not enough studies about the differences between the neural profiles of wrestlers and non-athletes, namely meta-analyses that quantify the difference between them.

The purpose of the work is to study the features of the brain electrical activity of wrestlers in comparison with non-athletes.

2. Materials and Methods

2.1. Description of the Experimental Method

The study involved thirty young men of 19.97±0.23 years old (with the height of 179.82±2.15 cm and the body weight of 78.61±1.68 kg) engaged in wrestling with sports experience of 10.7±0.8 years (with the qualification "Master of Sports"), and thirty young men of 19.25±0.18 years old (with the height of 178.35±2.25 cm and the body weight of 77.93±1.45 kg), not involved in sports (non-athletes).

Inclusion criteria are:

- for groups of athletes: active athletes of 19-20 years old, engaged in wrestling for 10 years with a total number of trainings of at least 21 academic hours (11 lessons per week), competing in the weight category up to 78 kg with the level of sports qualification ¨Master of Sports¨;
- for groups of non-athletes: practically healthy untrained youths of 19-20 years old who have undergone a medical examination and go in for physical education under the university program.

Exclusion criteria are:

- examined persons taking medications and biologically active supplements;
- examined persons with somatic diseases;
- examined persons with acute respiratory diseases or acute respiratory viral infections.

The study of the brain electrical activity was performed using the method of EEG with its registration in the transitional period of sports training (in the recovery mesocycle) [5].

EEG recording and analysis were carried out according to the generally accepted method using an automated complex consisting of EEG-16S electroencephalograph (Medicor, Hungary), laboratory interface and IBM PC computer. For EEG recording, a standard frequency band of the amplifying tract was chosen (the upper limit of the frequency range is 70 Hz, and the time constant determining the lower limit is 0.3 s). The signals were processed using the Fourier transform, obtaining EEG power spectra for analysis. For this purpose, the Polygraph program was used.

The current EEG was recorded in 2 leads (C3 and C4) according to the standard "10-20" system, which corresponds to the projection on the central area of the associative cortex. It is believed that EEG registration at these points reflects the type of the dominant EEG rhythm [5,6]. These zones are the most informative in the study of interhemispheric relations [5].

The localization of the electrodes was as follows: C3 - left central; C4 - right central; two combined reference electrodes over the mastoid bone of the skull (behind the ear); ground electrode on the wrist of the left hand. A special EEG helmet in the form of a rubber mesh was used to fasten the electrodes. In places where the electrodes were applied, the skin was thoroughly degreased with a mixture of alcohol and ether.

Recording of EEG potentials was carried out in three epochs with 15 series in each one: 1st epoch - closed eyes (Cl); 2nd epoch - open eyes (O); 3rd epoch - closed eyes (Cl).

During one experiment, EEG segments were recorded, which made it possible to obtain 40 power spectra for leads from the left and right hemispheres (20 with closed eyes closed, 20 with open eyes). The analysis epoch for each spectrum was 2.56 s. For the current EEG, the value of the normalized spectral power (μV2/Hz) was calculated for each selected frequency range and for each hemisphere separately.

For EEG analysis, the following frequency ranges were taken into account: delta rhythm (1-4 Hz), theta rhythm (4-8 Hz), alpha rhythm (8-14 Hz), beta1 rhythm (14-25 Hz) and beta2- rhythm (25-30 Hz).

Next, we analyzed CR, which characterizes the dynamic properties of cortical neurons when visual signals enter the cortex (closed eyes – open eyes) and when the flow of sensory signals "open eyes – closed eyes" is interrupted. CR was calculated according to the formula [7]:

$$\mathrm{CR} = \mathrm{X}\ (\text{closed eyes})/\mathrm{X}\ (\text{open eyes}), \qquad (1)$$

where CR has conv. units, X is the mean value of alpha-rhythm power (μV2).

CR value greater than 1.0 indicates a decrease in the alpha rhythm and, accordingly, an increase in reactivity, and the value less than 1.0 indicates an increase in the alpha rhythm and a decrease in the reactive properties of neurons in the cerebral cortex [7].

2.2. Statistical Analysis

Statistical analysis was performed using Microsoft Excel and "STATISTICA-10.0". The normality of distribution was tested using the Shapiro-Wilk test [287]. For pairwise comparison of groups, the nonparametric Wilcoxon test was used. The median (Me) was used as a measure of central tendency, and the lower (Q1) and upper (Q3) quartiles (25th and 75th percentiles) were used as measures of dispersion.

3. Results

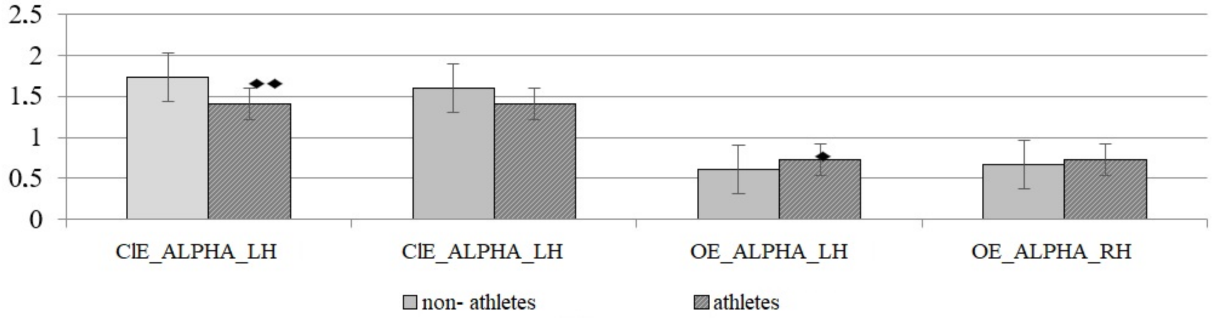
Table 1 shows that the alpha rhythm of athletes and non-athletes is statistically different. For athletes with closed eyes in the right hemisphere it was 1.21±0.10 μV2/Hz, and in the left hemisphere 1.23±0.10 μV2/Hz, and for athletes with open eyes it was 0.83±0.06 μV2/Hz and 0.85±0.05 μV2/Hz, respectively. In non-athletes, with closed eyes in the right hemisphere, this indicator was 1.42±0.10 μV2/Hz and 1.44±0.10 μV2/Hz, and with open eyes it was 0.99±0.05 μV2/Hz and 1.03±0.06 μV2/Hz, respectively. At the same time, with closed eyes, the difference in the range of alpha waves between the two groups in the left hemisphere was 17.07% ($p<0.05$), and in the right it was 17.35% ($p<0.05$). With open eyes in the left hemisphere, the difference was 21.17% ($p<0.01$), and in the right it was 19.27% ($p<0.05$).

Analysis of CR, which characterizes the dynamic properties of cortical neurons upon receipt of visual signals into the cortex and interruption of the flow of sensory (visual) signals in the experimental paradigm (Closed_Open_Closed), was calculated as the ratio of the power of the alpha rhythm with open eyes to closed.

Table 1. Indicators of normalized power (μV2/Hz) of EEG rhythms recorded in athletes and non-athletes

Indicators (units)	Athletes	Non-athletes	Percentage difference (%)	95% Confidence interval of the difference		t	P
				Lower Upper	Lower Upper		
DELTA_ClE_LH (μV2/Hz)	1.81 (1.72-1.90)	1.91 (1.56-2.24)	5.52	-0.37	0.147	-0.90	0.49293
DELTA_ClE_RH (μV2/Hz)	1.80 (1.71-1.89)	1.96 (1.59- 2.33)	8.88	-0.49	0.10	-1.31	0.205889
THETA_ClE_LH (μV2/Hz)	1.35 (1.28-1.41)	1.42 (1.17-1.67)	5.18	-0.23	0.11	-0.89	0.484350
THETA_ClE_RH (μV2/Hz)	1.35 (1.27-1.41)	1.39 (1.14-1.70)	2.96	-0.26	0.13	-0.66	0.440522
ALPHA_ClE_LH (μV2/Hz)	1.23 (1.12-1.33)	1.44 (0.95-1.85)	17.07	-0.43	-0.00	-2.12	0.054149 ♦
ALPHA_ClE_RH (μV2/Hz)	1.21 (1.11-1.31)	1.42 (1.00-1.91)	17.35	-0.45	-0.02	-2.12	0.038723 ♦
BETA1_ClE_LH (μV2/Hz)	0.48 (0.43-0.51)	0.53 (0.44-0.64)	10.41	-0.13	0.05	-0.78	0.314667
BETA1_ClE_RH (μV2/Hz)	0.46 (0.42-0.50)	0.51 (0.43-0.57)	10.86	-0.14	0.04	-1.05	0.393335
BETA2_ClE_LH (μV2/Hz)	0.31 (0.28-0.34)	0.29 (0.14-0.40)	-6.45	-0.07	0.11	0.39	0.571646
BETA2_ClE_RH (μV2/Hz)	0.28 (0.25-0.31)	0.28 (0.12-0.39)	0	-0.09	0.08	-0.10	0.958990
DELTA_OE_LH (μV2/Hz)	1.60 (1.54-1.65)	1.69 (1.45-1.85)	5.62	-0.25	0.08	-1.07	0.271156
DELTA_OE_RH (μV2/Hz)	1.64 (1.57-1.70)	1.78 (1.50-1.90)	8.53	-0.36	0.05	-1.48	0.113249
THETA_OE_LH (μV2/Hz)	1.19 (1.15-1.23)	1.26 (1.08-1.38)	5.88	-0.19	0.06	-1.07	0.271156
THETA_OE_RH (μV2/Hz)	1.22 (1.17-1.27)	1.33 (1.12-1.42)	9.01	-0.27	0.04	-1.48	0.113249
ALPHA_OE_LH (μV2/Hz)	0.85 (0.80-0.90)	1.03 (1.73-1.23)	21.17	-0.31	-0.01	-2.27	0.010140 ♦♦
ALPHA_OE_RH (μV2/Hz)	0.83 (0.78-0.89)	0.99 (1.75-1.22)	19.27	-0.30	-0.02	-2.41	0.017519 ♦
BETA1_OE_LH (μV2/Hz)	0.40 (0.37-0.42)	0.47 (0.38-0.54)	17.5	-0.10	0.02	-1.16	0.188050
BETA1_OE_RH (μV2/Hz)	0.40 (0.37-0.43)	0.44 (0.38-0.51)	10.0	-0.10	0.04	-0.73	0.459021
BETA2_OE_LH (μV2/Hz)	0.28 (0.25-0.30)	0.30 (0.13-0.45)	7.14	-0.12	0.07	-0.52	0.837038
BETA2_OE_RH (μV2/Hz)	0.26 (0.23-0.28)	0.29 (0.11-0.42)	11.53	-0.13	0.06	-0.72	0.813017

Notes: DELTA, THETA, ALPHA and BETA are rhythmic components of EEG, ClE are the closed eyes, OE are the open eyes, LH is the left hemisphere, RH is the right hemisphere; ♦ – $p<0.05$; ♦♦ – $p<0.01$, significance of differences according to the Wilcoxon test.



Notes: ALPHA is EEG alpha rhythm, ClE are the closed eyes, OE are the open eyes, LH is the left hemisphere, RH is the right hemisphere; ♦ – $p<0.05$; ♦♦ – $p<0.01$, significance of differences according to the Wilcoxon test.

Figure 1. Values of CR of EEG alpha rhythm in athletes (n=30) and non-athletes (n=30)

The figure shows that in athletes, alpha desynchronization is more manifest in the left hemisphere, reflected in CR (O_R), and indicates a functional imbalance of brain activation, suggesting increased cortical activation in response to a stimulus, the difference in this parameter was 20% ($p < 0.05$). On the other hand, in athletes, alpha synchronization was found in the left hemisphere, reflected in the parameter (ClE) at the level 1.74±0.41 against 1.41±0.22 in non-athletes. The difference in this parameter was 18% ($p<0.01$), which probably represents a functional correlate of inhibition, which is often observed in a calm state. In the right hemisphere, CR of the alpha rhythm in the studied groups did not differ.

4. Discussion

Our studies show that in wrestlers, the neural advantage over non-athletes is manifested only in a decrease in alpha rhythm fluctuations. As it is known, the alpha rhythm consists of waves with a frequency of 8-14 Hz. It is the most dominant frequency in EEG of adults and reflects inhibitory function, and is also the most widely studied in the scientific literature [6-9].

We determined that in wrestlers the reactivity of EEG alpha rhythm is most manifested in the left hemisphere, which is responsible for the implementation of the processes of abstract, symbolic and intellectual activity. It is known that the right hemisphere controls the main sensory functions of the left side of the body. And since, according to modern literature data, the majority of elite-level combatants are “left-sided”, their right hemisphere should reflect increased cortical activation [6]. Consequently, changes in the electrical activity of rhythms of the right hemisphere of the brain can serve as a reliable marker of the influence of various (training, correctional, etc.) effects of activation of the motor centers of the brain of athletes.

Electrical oscillations of the cerebral cortex at a frequency of 14-30 Hz (beta rhythm) reflect the processing of information associated with motor skills [9]. The lower power of the beta rhythm in wrestlers indicates increased excitability of motor cortex neurons, which is associated with faster motor responses [8]. Recent neuroimaging studies have shown that a decrease in beta rhythm power in athletes occurs when imagining or observing movement, leading to an increase in mental involvement in motor-related processing [8]. In our studies, it was found that the group of athletes had lower beta-rhythm values compared to non-athletes, which indicates increased excitability of motor cortex neurons, however, the differences found did not reach statistical significance.

The lowest frequency is the delta rhythm, represented in the picture of the current EEG by slow waves with a frequency of 1-4 Hz [5]. Since in EEG of a healthy person it is most pronounced during sleep, the absence of significant differences in this range between the two studied groups is quite understandable.

Theta rhythm consists of rhythmic oscillations with a frequency of 4-8 Hz. The generation of theta oscillations is activated by the frontal cortical areas, which are responsible for the processes of attention [1,4]. Therefore, frontal theta activity is considered an indicator of attention and increased mental activity.

As we can see from the data presented in the table, our studies did not reveal significant differences in this indicator. This is probably due to the fact that the design of the study did not imply an increased mental load. The obtained results are generally consistent with the available scientific data. A. D. Duru and M. Assem [10] reported that in karate athletes, frontal theta activity increased only when performing motor and cognitive tasks, and according to I. Polikanova, S. Leonov, A. Isaev and L. Liutsko [11], freestyle wrestlers in a calm state are characterized by a low frequency theta rhythm.

Evaluating the obtained results, it can be assumed that in the group of athletes the cognitive-motor indicators are better, the neural response is faster. We assume that in athletes, neural performance is seen as the integration of changes in neuroanatomical structure (neural plasticity), neural skills of higher cognitive processing and neural network as a result of long-term training in specific sports. The accumulated data confirm our assumption [11-20]. Although the presented differences may indicate functional changes in alpha levels as a result of intense training, however, based on the published results of recent years [1,4], it would not be true to say that it is sports activity that leads to the observed differences. For example, it is very likely that the two studied groups can statistically differ in a number of important aspects that affect brain activity, such as individual typological personality characteristics [9,10], as well as the level of fatigue or drowsiness [11]. According to modern scientific data, genetic, anatomical and psychological factors have a significant impact on the strength and range of basic levels of the alpha rhythm in the human EEG [7].

Thus, the observed differences in alpha rhythms at rest can also be considered from the point of view of hereditary genetic characteristics, which may be predictors of sports success or consequence of the influence of wrestling and intense exercise.

5. Conclusions

We concluded that wrestlers recruited fewer neural resources without compromising performance, supporting the hypothesis of neuronal flexibility in the brains of athletes compared to non-athletes. The results of the study can be used by coaches to develop effective training methods. Autoregulation of brain activity according to given patterns will help athletes achieve an optimal state before an important sporting event. EEG parameters such as alpha waves are targets that athletes can adjust to drive adaptation processes, for example using biofeedback.

Our results are of theoretical and applied significance, since the presented methods make it possible to adequately and reliably assess the features of the functional state of the central nervous system of athletes involved in acyclic sports, which can be used in sports selection. The traditional talent search is primarily based on determining the level of physical fitness. The neural approach presented by the authors can be a valuable addition to the search for gifted athletes.

Future EEG-based research will add significant value to the current understanding of the neural mechanisms underlying athletic performance.

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