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Electrophysiological Neuromuscular Systemic Characteristics of Athletes in Power Training

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Abstract—This study is based on the analysis of electrophysiological characteristics describing the neuromuscular system of athletes during their training sessions, depending on their specialization and level of sport skills. It has been shown that the physiological changes securing the perfection of strength training in weightlifting athletes are mainly concentrated in the peripheral part of their neuromuscular system, namely, at the level of muscles themselves and neuromuscular junctions, and reflected in the electromyogram characteristics as arbitrary movements and M response parameters. At the same time, physiological rearrangements in combat athletes touch the peripheral mechanisms and the central component in the regulation of motor activity and are reflected in the parameters of visual and somatosensory evoked brain potentials. The results disclose an entire set of new important approaches to the functioning of different compartments in the nervous system and the neuromuscular apparatus in athletes of different specializations. They can serve as the basis for the development of practical recommendations on the organization of sports-specialized selection at different stages of athletic perfection, as well as for the physiological support of training process and methods of operating control.

Keywords: electromyography, electroencephalography, evoked brain potentials, athletic training, weightlifting, single combat

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There are many confirmations in the literature on changes in the functional condition of the central nervous system and human neuromuscular apparatus due to static [1, 2] and dynamic [3, 4] muscular loads. However, the problem of physiological support of motor actions in athletes adapted to complicatedly coordinated muscular work of different specializations is so far insufficiently studied.

It is known that the development of physical abilities is supported by a combination of biochemical, structural, and functional changes in the body in the process of training, which characterizes the mobilization of reserve capacities in different systems. For example, the muscular strength development is characterized by muscle hypertrophy and the accumulation of adenosine phosphate (ATP), creatinine, and glycogen. The maximum oxygen consumption (MOC) increases and the respiratory and cardiovascular systems mobilize their reserves with the development of endurance [5]. The development of quickness increases the lability and excitability of motor centers in the CNS. Different stages of adaptation are characterized by the assimilation of even more reserves and the new integrational level in the functioning of different body systems [6]. It is also known that the development of physical abilities in an individual life course is accompanied by functional rearrangements in the neuromuscular system [7, 8], while the formation of sports skills is accompanied by substantial changes in the bioelectrical activity of the brain [9] and the electrical activity of skeletal muscles [10, 11].

An important mechanism for the development of physical abilities is economization that characterizes the increased functional efficiency of activated systems [12, 13]. For example, the development of muscular strength is accompanied by a synchronized work of motor elements, while the development of endurance or quickness is accompanied, respectively, by enhanced oxygen utilization or increases in the lability and quickness of motor responses [14].

During the athletic adaptation to muscular loads, increased resistance of individual systems of the body to the lactate accumulation is observed in an athlete's tissues and cells in cyclic types of motor activity, as well as the increased hypoxic stability in the sports associated with endurance [15, 16]. The mechanism of overcompensation is equally manifested in the development of strength (the accumulation of ATP, creatinine phosphate exceeding the initial level, hypertrophy of muscular fibers) and the increased endurance (accumulation of glycogen, free fatty acids, and an increase in MOC) [17].

The leading factor determining athletic skills in many sports is strength abilities (SAs) [18]. At the same time, SAs are nonhomogeneous by their nature and may essentially vary in their manifestations and physiological support among athletes of different specializations [19]. There are differences between SAs in general and their combinations with other physical abilities (speed-strength abilities, strength agility, and strength endurance). SAs in general are manifested in relatively slow contractions of muscles in the exercises performed with almost extreme loads (such as squats exerted with quite heavy weights) and in muscle tension of isometric (static) type. They are characterized by greater muscle tension and manifested in overcoming, yielding, and static operating modes of muscles. SAs in general are defined by the physiological diameter of a muscle and the functional capacities of the nervous-muscular apparatus [20, 21]. The speed-strength abilities (SpSAs) are characterized by not extreme muscle tension, performed with a significant speed, but not reaching, as a rule, extreme values. They manifest themselves in motor actions requiring, apart from a considerable strength of muscles, the agility of movements (e.g., push-offs in high and long jumps, and the final force in throwing sports). The greater an athlete's external load (e.g., in weight lifting for chest), the more significant the strength component, whereas the importance of speed-related component increases with lesser loading (e.g., a javelin throw) 22, 23].

Some sports are characterized by particular types of SAs, such as strength endurance and strength agility. Strength endurance is the ability to resist to tiredness generated by relatively long and considerable muscular tensions [24]. Strength agility is necessary in the muscular work modes characterized by alterations and in a sporting activity where varying and unpredictable situations are present (karate, wrestling, etc.) [25]. The mentioned ability can be defined as a quality to correctly differentiate among muscular tensions of varying levels in unpredictable situations and under combined modes of muscular work [26, 27]. The available literature data [28, 29] allow us to state that the level of absolute human strength is more determined by environmental factors (training, independent exercises, etc.), whereas the indicators of relative strength are more associated with genotypic effects.

The development of motor abilities in athletes would obviously be more efficient if the training process is organized considering the physiological regularities underlying the formation of these abilities. The athletic requirements may vary, depending on sports specializations and different stages of skill perfection, and, therefore, the problem of physiological substantiation in the choice of training strategies continues to be of great importance.

The goal of this study was to identify the dependence of electrophysiological characteristics in the neuromuscular system of athletes during training on their sports specialization and skill level.

METHODS

The study involved 60 men aged 18 to 23 years (the mean age was 19.8 ± 2.8 years). The athletes were divided by the nature of training process into two specialization groups—combats (athletic karate) and Weightlifting (Powerlifting). Each group was divided into two subgroups according to the level of skills in sports. The low-skilled subgroups (LS) included athletes with less than one-year of training experience in a given specialization and having no adult qualifications in sports. The highly skilled (HS) subgroups included athletes with more than three years of training experience in the chosen specialization and certified as a master of sports or candidates to a master of sports. Thus, experimenters formed four groups of observation, which differed from one another by the specialization of training process and sports qualification, and each group included 15 athletes of the same age.

The study was performed using a Neuro-MVP-2 electroneuromyograph (Neurosoft scientific-production association, Ivanovo, Russia), surface electrodes looked like metallic discs of 1 cm^2.

Electromyography (EMG)

Depending on the chosen method of study, electrodes were placed on different muscles. In the interference electromyography, the electrodes were located on the following muscles: m. biceps brachii, m. pectoralis major, m. trapezius, and m. latissimus dorsi. The electrodes were used with fixed distance and located in the projection of the muscle's motor area along the muscle fibers. The earth electrode was placed on the opposite limb.

In stimulus-evoked electromyography, the electrodes were placed on the following muscles: abductor pollicis brevis medianus and flexor pollicis brevis medianus. The stimulating bipolar electrode was placed along the projection of the nerve that innervated the given muscle. The earth electrode was located on the upper third of the forearm.

When recording the interference surface EMGs and after the electrodes were attached, the athletes were asked to perform the following preparatory exercises used in weightlifting and combat sports as basic. The modelled movements were represented by the basic exercises from the general system of technical training in these sports, such as, lifting a 16-kg weight for the weightlifting group and a punch to the paw (a specialized accessory) for the karate group. Performing these technical maneuvers in a real situation is always associated with the generation of considerable exertion in the muscles supporting the realization of the given motor actions [11].

Recording Somatosensory Evoked Potentials (SSEPs)

The subject was asked to accommodate himself to the armchair, providing light- and sound-free environment, and relax himself. The stimulation (rectangular 0.2- to 03-ms electrical pulses at a stimulation frequency of 3–5 Hz) was generated in the distal right-hand compartments, regio carpalis, and in the projection of the median nerve. The electrode was placed in a way for the cathode to be more proximal. The earth electrode was placed on the stimulated limb more proximally relative to the point of stimulation, i.e., on the upper third of the shoulder (Fig. 1). In line with the recommendations [30] the SSEPs were recorded from Erb's point (the interior arc of the clavicle at the junction point of the sternocleidomastoid muscle). The second point of recording was from the cervical spine and the third one from the head surface. The electrodes at Erb's point were placed on the region of both superclavicular fossae (*Erb'i–Erb'c*). The active electrode was on the stimulated side (*Erb'i*). The active electrode for the cervical spine was placed on the spinous process of cervical vertebra VII, while the reference was placed on the *Fpz* (*Cerv7–Fpz*) (Fig. 1). The active electrodes on the head surface were placed at the points *Cp3* (contralateral) and *Cp4* (ipsilateral), which were located between the central and parietal electrodes. The reference electrode was located on the *Fpz* point or at the contralateral Erb's point (*Erb'c*), depending on the goal of the study. The 2-channel recording was applied for the study of SSEPs. The representation of the curves one under another on the same screen helped to differentiate the components of the proximal and distal fields.

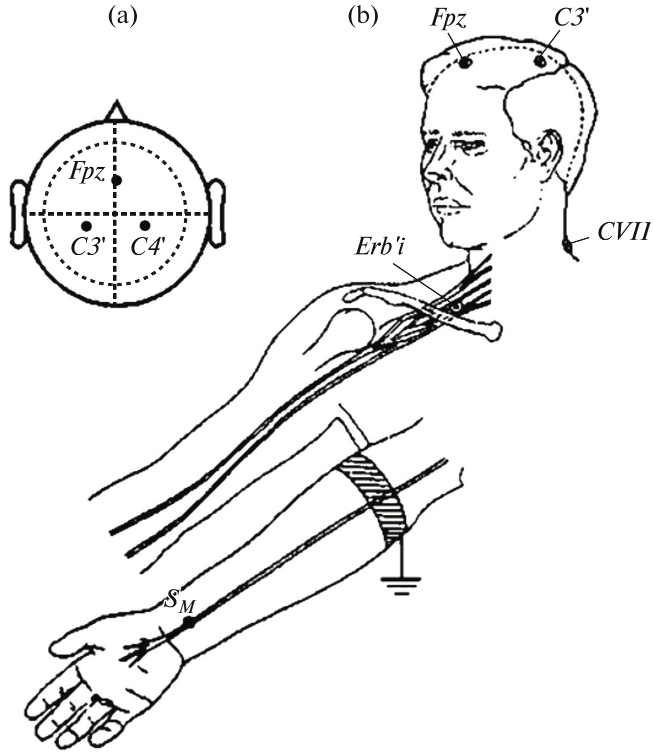

Fig. 1. Location of stimulation and leading electrodes (a) on the surface of the head and (b) on the body in recording somatosensory evoked potentials from upper limbs (nervus medianus) [30].

Recording Visual Evoked Potentials (VEPs)

In line with the recommendations [30] on recording VEPs, the active electrodes were placed on the head by the International 10–20 Scheme with the observance of a symmetry and equality in the inter-electrode distances. The VEPs were recorded at frontal anterior-temporal, temporal, central, parietal, and occipital leads. The visual stimuli (flashes of light), 60 in number, were sent to the eyes closed from a distance of 30 cm at a frequency of 1000 Hz. The pass band of the amplifier was 0.5–35 Hz. The investigations were performed with a monocular stimulation under scotopic conditions.

The obtained quantitative data were described for each sample, using the distribution parameters (the Shapiro–Wilk *W* test). If the distribution of data met the normal law, the parametric criteria were applied, but in case of the condition being unmet nonparametric criteria were chosen. Both parametric (the Cramer–Welch criterion) and nonparametric (Mann–Whitney *U* test) criteria were applied for the independent groups. The homogeneity of dispersions in the compared samples was previously tested with the normal distribution law by the Fisher–Snedecor test. The analysis was performed using the Statistica 6.1 software package. The value $p < 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

The data analysis has shown that the development of strength abilities in combat athletes (CAs) and weightlifters (WLs) has a set of principal differences. Significantly ($p < 0.05$) lower values of bioelectrical activity (BA) in all muscles were observed in the highly qualified weightlifters (HS WLs), when they lifted a standard weight load (a 16-kg kettlebell), in both the amplitude and the mean frequency of pulses, compared with the low-qualified athletes (LS WLs), (Table 1). These changes obviously reflected the specificity of training loads in weightlifting. A decrease in the muscle bioelectrical activity (MBA) indicates that the level of strength endurance and the functional

Table 1. Bioelectrical activity of muscles in athletes of different qualifications due to physical loads (lifting a kettlebellt in weightlifters, a punch to the paw in combat athletes) (Me (Q_{25}–Q_{75}))

Muscles	Low-skilled athletes				Highly skilled athletes			
	maximum amplitude, μV		average frequency, 1/s		maximum amplitude, μV		average frequency, 1/s	
	WLs	SCs	WLs	SCs	WLs	SCs	WLs	SCs
m. biceps brachii	2578.6 (1525; 3564.5)*	1564.3 (593; 1858)#	50.3 (25; 74)	72.1 (15; 117)#	541.4 (288; 792)	1940.4 (553; 4258)	48.4 (11; 71.3)	53.5 (2.7; 114)
m. pectoralis major	2224.5 (571.5; 3362)*	2327.7 (809; 4039.5)#	21.1 (9.5; 47.7)*	6.63 (0.33; 17.35)	838.3 (111; 924)	3248.3 (143.5; 4346)	1 (0.2; 2.09)	4.7 (2.3; 7.8)
m. trapezius	3326.8 (1712.5; 4658)*	4701.3 (1436; 5924)#	114.7 (70; 269)	157.1 (136; 181)#	1404 (709.5; 2411)	5783 (492; 6964)	96.83 (53.5; 152)	74.2 (2.8; 118)
m. latissimus dorsi	2169.3 (695.5; 3152.5)*	4769.2 (984; 6069.5)#	58.4 (17.5; 97)*	34.7 (3.67; 70)#	1285 (99.7; 2548)	2054.3 (125; 2697)	1.4 (0.7; 9.3)	27 (14.5; 53)

WLs, weightlifters; SCs, combat athletes; * statistically significant difference ($p < 0.05$) between the groups of low-skilled and highly skilled weightlifters, # statistically significant difference ($p < 0.05$) between the groups of low-skilled and highly skilled combat athletes.

reserve increase in the muscular system with the perfection of sports skills in athletes. The development of strength endurance allows an athlete to maintain a load for a long time and make repeats in insignificant time intervals, as well as it imparts the ability to generate the maximum strength. The speed and coordination of movements are of no principal importance in this case. The movements are performed under standard conditions in a standard initial position with the standardized equipment. An important quality here is a capacity for motor stereotypes, i.e., the ability to perform exercises by standard schemes minimizing deviations [14]. Therefore, the sport training in weightlifters is primarily oriented to the formation of the qualities, such as strength endurance, the capacity for maximum muscular contractions, and the ability to reproduce stereotyped motor actions (Fig. 2).

The ability to prolong the duration of the local strength work is known to be associated with the strength and capacity of the alactic anaerobic mechanism for energy supply, which involves improving the phosphagen energy supply system through increasing the strength of the anaerobic alactic process and widening the capacity (increasing the number of intramuscular energy sources) [5]. However, as the results of this study have shown, apart from biochemical rearrangements, the strength endurance development also involves the physiological mechanisms related primarily to the eonomization and ergonomization of the movements being performed. This is reflected on an electromyogram in a simultaneous decrease in the

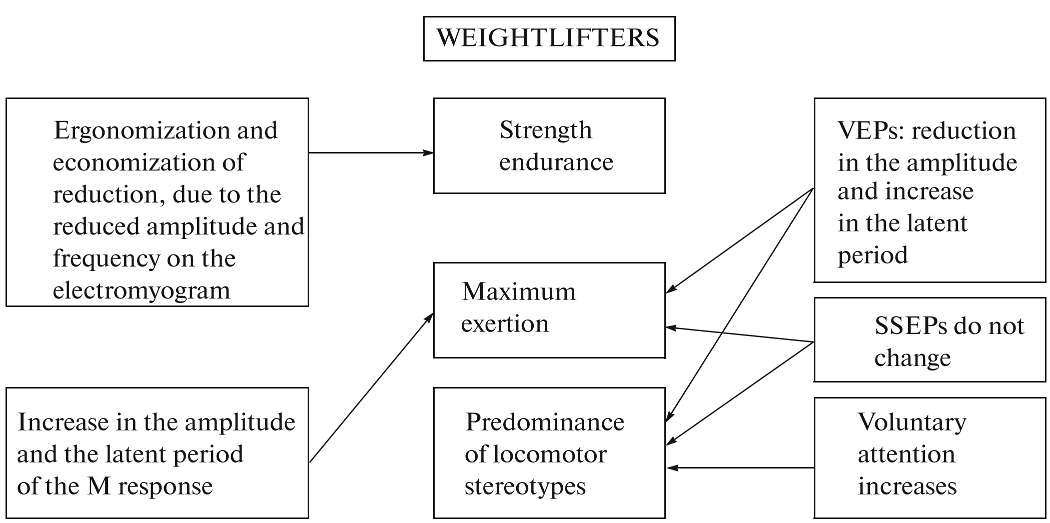

Fig. 2. Physiological indicators for the formation of strength abilities in weightlifters. VEPs, visual evoked potentials, SSEPs, somatosensory evoked potentials.

Table 2. Bioelectrical responses of skeletal muscles in the forearm of weightlifters and combat athletes of different skills to electrostimulation (M response) (Me (Q_{25}–Q_{75}))

Parameters	Low-skilled athletes		Highly skilled athletes	
	WLs	SCs	WLs	SCs
Amplitude, mV	2.03 (1.39; 3.56)*	1.5 (1.35; 1.83)$^{\#}$	2.48 (1.72; 4.31)	4.7 (3.54; 5.09)
Latent period of M response, ms	3.35 (2.75; 3.53)*	2.2 (2.15; 2.60)$^{\#}$	3.5 (2.85; 3.65)	3.2 (3.0; 3.55)

WLs, weightlifters; SCs, combat athletes; * statistically significant difference ($p < 0.05$) between the groups of low-skilled and highly skilled weightlifters, $^{\#}$ statistically significant difference ($p < 0.05$) between the groups of low-skilled and highly skilled combat athletes.

amplitude and frequency of electrical activity in skeletal muscles against their voluntary contraction at a given value (Table 1). A decrease in the energy expenditure of muscular strength, due to optimizing the ergonomicity of contractions and more economical expenditure of energy resources, allow athletes to reduce the number of lomotor elements recruited for the performance of standard movements, which finds its reflection in the nature of the bioelectrical activity in muscles.

At the same time, athletes form their maximum level of strength in two ways by: (a) enlarging their muscle mass; (b) perfecting intramuscular and intermuscular coordination [14]. When studying the maximum amplitude of the M response into a contractile response to the nerve electrostimulation (Table 2), we observed its substantial growth in weightlifters at the stage of sports skills, since it is this indicator that reflects the total amount of muscular fibers involved into contraction at the maximum of nerve stimulation. The latent period of a response (Table 2) also became longer, which may reflect a predominance of slow-twitch fibers that are characterized by a greater force of contractile responses [16]. In addition, a decrease in the conduction velocity of impulses through the neuromuscular contacts creates conditions for the summation of impulses and secures the synchronization of contractile responses and, therefore, their amplitude.

Further analysis dealt with the motor stereotype, i.e., on a stable complex of conditional reflective motor responses, realized in a certain order to secure postural tonic functions. The analyzed data from Table 3 showed that the latent period of VEPs in HS weightlifters was significantly longer along with a reduction in their amplitude.

As the obtained data show, the observed prolongation of the latent VEP period in HS weightlifters may probably be associated with the increased number of synaptic contacts and, respectively, with the decreased speed of response to the incoming irritation (Table 3). An increase is simultaneously observed in the VEP amplitude of HS weightlifters (Table 3), which, probably, reflects a desynchronization in the work of neuronal ensembles and a decrease in the quality of identification.

In general, the obtained results indicate the formation of stereotypic motor acts and an increase in the resistance to distracting (interfering) factors with the growing qualification in weightlifting. The strength training in weightlifters is primarily aimed to form the qualities, such as strength endurance, the ability to reach the maximum of muscular forces, and the ability to reproduce stereotypic motor actions (Fig. 2).

The strength training in combat athletes of (CAs) has a differently oriented task. Their sports activity is associated with the necessity to hit punches and block responsive actions from the rival. A combat athlete has to permanently control the situation and adequately react to hardly predictable changes, maintaining a high level of motor coordination [25]. This circumstance finds its reflection in the specificity of changes in the bioelectrical activity of muscles in combat athletes with their growing qualification. The synchronization of motor elements on the electromyogram curve is reflected in a decrease in the frequency (for all muscles) and an increase in the maximum amplitude of the bioelectrical activity of muscles (for the exception of m. latissimus dorsi) in performing standard movements (Table 1). Thus, a necessary condition for a HS CA is the formation of "explosive force," when the nature of pulsation of motorneurons plays an important role, i.e., the frequency of their pulsation at the beginning of the discharge and the synchronization of motorneuron pulsation at the peak of strength. The higher importance in the manifestation of explosive force belongs to the speed-related contractile properties of muscles, which depend, to a considerable degree, on their composition, i.e., the ratio of fast and slow fibers. Apart from this, an increase in the speed of impulse conduction through the neuromuscular junctions will also contribute to the generation of explosive force. Both factors are manifested in a shorter latent period of M response in combat athletes, compared with weightlifters (Table 2).

The second important quality of motor readiness is the ability of combat athletes to correctly differentiate muscular efforts of varying intensities in unpredictable

Table 3. Indicators of visual (VEPs) and somatosensory evoked potentials (SSEPs) of the brain in weightlifters and combat athletes of different qualifications ($X \pm m$) (Me (Q_{25}–Q_{75}))

	Indicators	Components	Groups			
			weightlifters		combat athletes	
			L	H	L	H
VEPs	Latent period, ms	*P*1	140 ± 3.8*	160 ± 2.8	165 ± 3.7#	158 ± 3.5
		*P*2	260 ± 4.2*	270 ± 1.7	270 ± 5.1#	266 ± 5.0
		*P*3	400 ± 1.9*	390 ± 5.8	390 ± 5.5#	384 ± 5.4
	Amplitude, μV	*P*1	6.0 ± 0.23*	1.0 ± 0.02	3.5 ± 0.12#	5.8 ± 0.14
		*P*2	5.4 ± 0.18*	0.3 ± 0.02	3.2 ± 0.16#	5.4 ± 0.19
		*P*3	2.9 ± 0.03*	0.5 ± 0.01	2.2 ± 0.15#	2.9 ± 0.13
SSEPs	Latent period, ms	*N*9	9.63 ± 0.14	9.8 ± 0.26	9.25 ± 0.12	8.8 ± 0.23
		*N*13	13.16 ± 0.14	12.8 ± 0.16	12.6 ± 0.24	12.54 ± 0.38
		*N*20	20.38 ± 0.22	20.51 ± 0.14	20.15 ± 0.11	19.44 ± 0.19**
	Amplitude, μV	*P*8–*N*9	7.23 (6.53; 8.3)	7.91 (6.33; 8.26)	7.2 (6.82; 8.17)	5.13 (4.65; 6.12)**
		*P*18–*N*20	4.1 (3.16; 4.93)	4.22 (3.32; 4.82)	3.82 (3.42; 4.67)	2.1 (1.83; 2.85)**
		*N*20–*P*23	4.23 (3.23; 5.2)	4.31 (3.12; 5.14)	4.16 (3.64; 5.23)	2.04 (1.23; 2.56)**

L, low-skilled athletes; H, highly skilled athletes; *P*1, *P*2, *P*3, positive components; *N*9, the potential of action in the nerve fibers of brachial plexus; *N*13, the response from the tubercles along the posterior columns of the spinal cord; *N*20, primary cortex activation of the somatosensory area; *N*9–*N*13, impulse conduction from the brachial plexus to the lower brainstem; *N*13–*N*20, conduction from the lower brainstem to cerebral cortex; *P*8–*N*9, activation of neurons in the ganglion of the brachial plexus; *P*18–*N*20, thalamocortical activity; *N*20–*P*23, the area of cortical projection of the hand. * Statistically significant difference ($p < 0.05$) between the VEP indicators in the groups of low-skilled and highly skilled weightlifters, # statistically significant difference ($p < 0.05$) between the VEP indicators in the groups of low-skilled and highly skilled combat athletes. ** Statistically significant difference ($p < 0.05$) between the SSEP indicators in the groups of low-skilled and highly skilled combat athletes.

situations and combined regimens of muscular work, which is manifested in combat conditions. The important manifestation of strength agility is a high degree of arbitrary tension and relaxation, which allow athletes to handle fights more economically, learn technical skills faster and better and use them during combats. The excessive tension interferes with the accuracy in the performance of movements, therefore, as our data have shown (Table 4) the ability of relaxation in combat athletes is significantly stronger, which is reflected in lower values of both the maximum amplitude and the average oscillation frequency on the electromyogram recorded at rest. In particular, these differences are significantly ($p < 0.05$) lower in HS SCs than in LS SCs already at rest for the pectoralis major, trapezoid, and latissimus dorsi muscles. The significant ($p < 0.05$) decrease in the average oscillation frequency in HS CAs is also valid for the pectoris major and latissimus dorsi muscles (Table 4).

Changes in the work of the nervous system are observed during training sessions of HS CAs, and as a result, the primary cortical activation of the somatosensory area comes significantly earlier, being reflected in a shorter latent period of components *N20* (Table 3). This indicates that HS CAs analyze sensory information at a higher speed and with less amplitude of potentials (Table 3), which confirms their quickness of response and deeper differentiation of motor responses to the stimuli.

One of the important indicators for the sports skill development in combat sports is the time of reaction. The time value for a response to a stimulus in CAs decreases as their skill grows. A reduction in the latent VEP period indicates a reduced number of synaptic contacts, while the wider amplitude points to the work synchronization between neuronal ensembles, which corresponds to a more complete analysis and recognition of a stimulus at the increased speed of response (Table 3).

A simultaneous increase is observed in the readiness of HS CAs to the perception and analysis of stimuli, which is evidenced by the emergence of an early negative wave of somatosensory evoked potentials, whereas in weightlifters, on the contrary, the ignorance of incoming stimuli is enhanced, which is evidenced by the emergence of the early positive wave (Fig. 3). A reduction in the latent period and the amplitude of somatosensory evoked potentials are observed in the frontal and occipital areas of HS CAs, compared with LS CAs (Table 5). These systems in weightlifters whose sporting activity are associated to a greater degree with stereotypic motor actions develop

Table 4. Electrical activity of muscles at rest in combat athletes of different skills (Me (Q_{25}–Q_{75}))

Muscles	Low-skilled athletes (n = 15)		Highly skilled athletes (n = 15)	
	maximum amplitude, μV	average frequency, 1/s	maximum amplitude, μV	average frequency, 1/s
m. biceps brachii	146.5 (53.8; 234)	0.4 (0.03; 1.3)	131.7 (21.7; 271.2)	0.08 (0.01; 0.17)
m. pectoralis major	682.7 (159; 1087)*	1.37 (0.85; 2.7)*	189.78 (16; 221.5)	0.25 (0.032; 1.7)
m. trapezius	178.2 (79.4; 343)*	3.25 (1.4; 6)	116 (26.4; 268.5)	2.1 (0.6; 5)
m. latissimus dorsi	98.5 (44.4; 174.7)*	3 (0.31; 6.7)*	58.5(27.5; 80)	0.2 (0.04; 1)

* Statistically significant difference ($p < 0.05$) between the indicators in the groups with low and high skills.

Table 5. Characteristics of somatosensory evoked potentials of the brain in combat athletes and weightlifters of different skills and specializations ($X \pm m$) (Me ($Q_{25} - Q_{75}$))

Indicators	Leads	Weightlifters		Combat athletes	
		L	H	L	H
Latent period, ms	Frontal area	13.16 ± 0.14	10.6 ± 0.26	9.25 ± 0.12	7.2 ± 0.23*
	Occipital area	18.3 ± 0.16	16 ± 0.22	13.2 ± 0.38	10.5 ± 0.19*
Amplitude, μV	Frontal area	7.23 (6.53; 8.32)	7.91 (6.33; 8.26)	7.2 (6.82; 8.17)	5.13 (4.65; 6.12)*
	Occipital area	4.23 (3.23; 5.25)	4.31 (3.12; 5.14)	4.16 (3.64; 5.23)	2.04 (1.23; 2.56)*

Frontal leads Fp_2–$Erb'c$, occipital leads O_2–$Erb'c$; L, low-skilled athletes; H, highly skilled athletes; * significance of differences between the groups of low-skilled and highly skilled athletes, $p < 0.05$.

to a lesser extent and hardly change with their qualification growth. The total scheme of physiological changes in combat athletes with their skills growth is presented in Fig. 4.

CONCLUSIONS

Physiological changes securing the perfection of strength readiness in weightlifters are mainly concentrated in the peripheral component of the nervous-muscular system on the level of the muscles themselves and neuromuscular junctions. They find their reflection in electromyogram characteristics in arbitrary movements and M response parameters. At the same time, physiological rearrangements in combat athletes equally involve both the peripheral mechanisms and the central component of motor activity regulation and find their reflection in the parameters of visual and somatosensory evoked brain potentials.

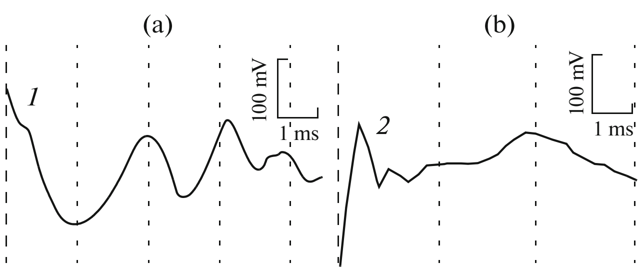

Fig. 3. Somatosensory evoked potentials of the brain in highly skilled athletes (frontal area, the $Fp1$–$Erb'c$ lead): (a) combat athletes, (b) weighlifters. (*1*) Early negative wave and (*2*) early positive wave.

There are differences between weightlifters and combat athletes in the functional character of the brain systems related to orienting response and selective attention securing the formation of motor responses to the external stimuli. As the athletic skills grow, the degree of arbitrariness in the use of these mechanisms and, respectively, the share of either mechanism vary during sports activities.

Combat athletes whose activities are related to the recognition of outer stimuli and the organization of motor actions in correspondence with these stimuli develop both systems: the arbitrary system for the formation of a motor response to a stimulus and the involuntary system for the recognition of qualities in a stimulus, which is evidenced by a reduced latent period and the amplitudes of somatosensory evoked potentials in the frontal and occipital areas in HS athletes. The indicated systems in weightlifters whose sports activities are more characterized by stereotypic motor actions develop less actively.

The obtained results disclose a full complex of important aspects in the functioning of different areas in the nervous system and the neuromuscular apparatus in athletes of different specializations. At the same time, they can serve as the basis for the development of practical recommendations on the organization of sports selection at different stages of athletic qualification, for the physiological substantiation of training

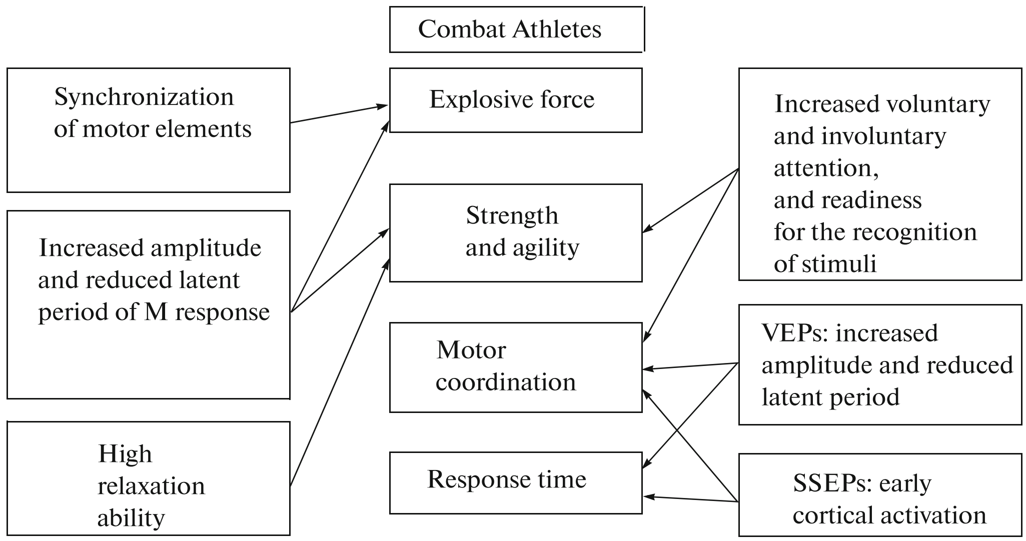

Fig. 4. Physiological indicators for the formation of strength abilities in combat athletes. See the designations in Fig. 2.

process and the development of operative control methods.

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