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OBJECTIFICATION OF FUNCTION TEST OF THE MUSCLES INVOLVED IN THE IMPLEMENTATION OF TARGETED KICKING ACTIONS OF FOOTBALL PLAYERS USING THE MULTICHANNEL REGISTRATION OF SURFACE ELECTROMYOGRAM METHOD

Privalova I. L.[1], Bobrovskij E. A.[1], Nikolaev S. G.[2], Kuranov V. B.[3], Mamaeva A. A.[1], Trubitsyn R. V.[1], Pushkina V. V.[1]

[1]Kursk State Medical University, Kursk, Russia
[2]OOO MC «Elf», Vladimir, Russia
[3]AO «Orto-S», Saint-Petersburg, Russia
E-mail: ir_priv@mail.ru

A study was conducted of the electrical activity and functional relationships of the muscles involved in the implementation of targeted kicking actions of football players using the multichannel registration of surface electromyogram (SEMG). SEMG of the young people regularly attending the arena football section of the Kursk State Medical University and participating in football matches were analyzed. It was revealed that sports training aimed at the development of targeted kicking actions of football players, contribute to the formation of functional muscle complexes involved in the axial rotation of the crurae and lateral displacement of the knee.
Keywords: vastus lateralis, vastus medialis, gastrocnemius, surface electromyogram.

INTRODUCTION

Knowledge of the physiological mechanisms of motion activity is the basis for planning the training process in any sport. Game sports are different in that they require the development of a variety of motion skills. Thence, for adequate organization of football training, the dynamic control of the results is required, comprising objectification of the functional state of the muscles, their interrelations and regulation.

Despite the fact that the electrical activity of the muscles most adequately reflects their functional state, studies using surface electromyogram (SEMG) have begun to be conducted relatively recently. In particular, this method was used to assess the activity, coordination and fatigue of muscles after intermittent training, including movements of various intensity carried out during a football match (walking, running, sprint). It was noted that SEMG makes it possible to compare muscle activity when performing various movements [1]. More recently new data were obtained on the role of the femoris muscles in the performance of targeted kicking actions of football players. An increase in the electrical activity of the adductors of the supporting and impact legs depending on the speed of a football kick was revealed [2]. A first attempt was also made to characterize the neuromuscular profile of the activation of vastus lateralis of the football players. For this, the vastus lateralis (VL) electrical activity of the dominant leg was continuously recorded

using SEMG during a 90-minute football match. The obtained results confirmed the relevance of the physiological approach to the problems of competitive football, which is proposed to be used for monitoring and planning exercising [3]. The analysis of modern publications draws attention to identifying the role of the femoris muscles in the productive game actions of football players. This seems consistent, given their anatomical and physiological features. In particular, the lateral broad muscle, occupying almost the entire anterolateral surface of the thigh, makes a significant contribution to the leg transfer phase function of the leg extension while walking and running, and to determining the length and frequency of the step in the support and push phases. Rapid dynamic contractions of this muscle are involved in the implementation of targeted percussion actions of football players. The dependence of the bioelectric activity of the functional muscle group (lateral wide muscle, gastrocnemius medial head) on the level of athletes' qualification [4].

Given the relevance of the physiological approach to the organization of football training and available research data on the role of the femoris and calf muscles in the implementation of targeted kicking actions of football players, the purpose of our work was to study the electrical activity and functional relationships of the muscles involved in the implementation of targeted kicking actions of football players, using the multichannel registration of surface electromyogram method.

MATERIALS AND METHODS

The survey was attended by young students of KSMU, who regularly take part in arena football section workouts and participate in football matches (n = 12). All subjects were clinically evaluated as healthy, were in good physical condition, and were highly resistant to orthostatic load. The research program was approved by the ethical commission of KSMU.

At the preparatory stage, the subjects were acquainted with the purpose of the study and a detailed description of the registration procedure using the surface electromyography method. Then they were provided with the instructions to follow during the recording, and their written consent was obtained. At registration of the description part of the study protocol, anthropometric data of the subject, information on the drugs used and other data on factors that may affect muscle function were specified. Then in places where the electrodes were supposed to be fixed the skin was treated with antiseptic medicine (70 % ethyl alcohol) with a napkin to reduce skin resistance in order to obtain a high-quality signal. The electrodes were fixed in accordance with the anatomical landmarks on the motor points of the studied muscles [5]. The study used felt electrodes with a fixed anode-to-cathode distance of 2 cm.

The electrical activity of the synergist – antagonist muscles involved in the implementation of movement in the knee joint was recorded: the lateral and medial wide muscles of the femoris, the gastrocnemius (caput mediale and caput laterale). The study of electrical activity was carried out in the mode of maximum spontaneous muscle tension. To standardize the signal, the subjects made three maximum isometric muscular contractions of 6 seconds with short breaks between them. The electromyogram was recorded synchronously with the muscles of the cognominal contralateral extremities. The

recording was carried out with the help of an 8-channel electroneuromyograph of expert class “Neuro-MVP-8” (“Neurosoft”, Ivanovo).

The recording was carried out before the start of the training session and 30 to 60 minutes after the training session, which included working out the targeted kicking actions of the players.

At the stage of signal processing, a turn-amplitude and spectral analysis of the data was performed. The minimum amplitude limit of the turn was set to 100 μV. The obtained data were checked for normal distribution using the Shapiro-Wilk’s tests and revealed that the frequency distribution do not obey the law of normal distribution. Therefore, the Ansari-Bradley criterion [6]. was used to assess the statistical significance of differences between samples, and Kendall correlation coefficient was calculated for evaluating functional relationships between the parameters of the electrical activity of the muscles.

RESULTS AND DISCUSSION

In the first series of studies the recording electrodes were located on the motor points of the vastus lateralis of the femoris and gastrocnemius (caput mediale). The subjects made maximum isometric muscular contractions of the lateral broad muscle of the thigh. Then the electrical activity of this muscle was recorded and electromyograms of the lateral broad thigh muscle on the left, as well as the gastrocnemius muscles (caput mediale) of the right and left limbs were simultaneously recorded.

The data of the turn-amplitude and statistical analysis of the results obtained are presented in Table 1.

The EA parameters of the musculus vastus lateralis were higher on the right leg than on the left; for the average amplitude of the EA the differences were statistically significant ($p<0.05$). The EA parameters of the gastrocnemius medial head on the left were higher than on the right ($p<0.05$) (see table). The values of the Kendall correlation coefficients calculated between the EA parameters of the musculus vastus lateralis on the right and left, indicated the presence of weak positive correlations in terms of the EA frequency and average amplitude (Table 1). Positive correlations of average strength were observed between the EA parameters of the medial heads of the left and right gastrocnemius muscles, as indicated by the values of r (0.633; 0.59; 0.617). Positive correlations were also detected between the EA of the studied muscles in the left extremity (0.388; 0.344; 0.219) and were absent in the right (see Table 1). Higher values of the electrical activity of the musculus vastus lateralis were recorded after the workout than before. At the same time, when comparing the contralateral limbs, the amplitude and frequency values of EA on the left were larger than on the right (see Table 1). The values of the Kendall correlation coefficients by the amplitude of the EA (0.224; 0.232) made it possible to predetermine the presence of weak positive correlations; and the frequency (0.359) shows the moderate connections. The amplitude and frequency of EA medial gastrocnemius muscles also increased significantly, with the amplitude on the left more than on the right, and the frequency on the right more than on the left. The correlation of the amplitude and frequency characteristics of the EA marginally decreased (see Table 1). Between all the EA parameters of the musculus vastus lateralis and the medial gastrocnemius muscle of the right limb, positive correlations of average strength were

detected. For the left limb, such connections were found only between the amplitude values of EA (see Table 1).

Table 1.

The parameters of electrical activity (EA) of the musculus vastus lateralis and gastrocnemius medial head (Me [Q1; Q3])

		The parameters of EA	Max. amp., μV	Avg. amp., μV	Avg. freq. 1/s
Before	Me	V.L. left	589,5 [283; 735]	202,5 [168; 304]	136 [32; 208]
		V.L. right	581 [438; 771]	267* [215;299]	147 [104; 200]
		M.G. (*caput mediale)* left	865 [299; 1010]	340 [177; 388]	160 [60; 280]
		M.G. (*caput mediale)* right	394*[297; 1287]	200*[181; 424]	136 [64; 236]
Before workout	Value *r*	V.L. left - V.L. right	0,085	0,227*	0,198*
		M.G. (*caput mediale)* left - M.G. (*caput mediale)* right	0,633*	0,590*	0,617*
		V.L. left - M.G. (*caput mediale)* left	0,388*	0,344*	0,219*
		V.L. right - M.G.(*caput mediale)* right	-0,141	0,06	-0,05
After workout	Me [Q1;Q3]	V.L. left	710,5 [474; 1023]	326 [228; 407]	164 [112;204]
		V.L. right	638 [338; 997]	264,5 [191; 362]	142 [72; 220]
		M.G. (*caput mediale)* left	1057 [850; 1465]	374,5 [290; 494]	242 [204; 272]
		M.G. (*caput mediale)* right	911,5 [701; 1221]	330,5 [290; 389]	260 [184; 304]
		V.L. left	710,5 [474; 1023]	326 [228; 407]	164 [112;204]
		V.L. right	638 [338; 997]	264,5 [191; 362]	142 [72; 220]
		M.G. (*caput mediale)* left	1057 [850; 1465]	374,5 [290; 494]	242 [204; 272]
		M.G. (*caput mediale)* right	911,5 [701; 1221]	330,5 [290; 389]	260 [184; 304]
	Value *r*	V.L. left - V.L. right	0,224*	0,232*	0,359*
		M.G. (*caput mediale)* left - M.G. (*caput mediale)* right	0,357*	0,303*	0,181*
		V.L. left - M.G. (*caput mediale)* left	0,443*	0,391*	0,065
		V.L. right - M.G. (*caput mediale)* right	0,395*	0,479*	0,487*

In the second series of studies, the recording electrodes were located on the motor points of the musculus vastus lateralis and the lateral head of the gastrocnemius. Before starting the registration of EA, the subjects also performed three maximum isometric contractions of the right musculus vastus lateralis of 6 seconds with short breaks between them. In this series of studies, the electrical activity of the musculus vastus lateralis was recorded, the amplitude and frequency values of which were higher on the right than on the left (see Table 2). The Kendall correlation coefficients (0.392; 0.351; 0.37) suggested the presence of connections of average strength between the EA of the muscles studied, which is consistent with the results of the first series of studies. The amplitude of the EA of the gastrocnemius muscle retracted from its lateral head on the left was statistically significantly higher than on the right ($p<0.05$). The frequency of EA on the contrary was significantly higher on the right than on the left ($p<0.05$). Between all parameters of the EA of contralateral muscles, positive correlations of average strength were observed (see Table 2). The correlations between the frequency EA values of the musculus vastus lateralis and the lateral gastrocnemius muscles were positive with average strength (0.302; 0.308) and did not change significantly after training (0.310; 0.253).

After the workout the amplitude and frequency of EA of the musculus vastus lateralis on the right were higher than on the left ($p <0.05$).

The amplitude values of the EA of the lateral gastrocnemius muscle were higher on the left than on the right ($p<0.05$). On the contrary, the average frequencies on the right were higher than those on the left ($p<0.05$). At the same time, moderate positive correlations were found only between the average values of the amplitude of the EA. A correlation analysis of the EA parameters of the musculus vastus lateralis and lateral gastrocnemius revealed the presence of weak negative correlations between the mean values of the amplitude of the EA (see Table 2).

In the third series of studies electrical activity was recorded from the medial vastus muscle (with maximum spontaneous right leg's muscle tension) and lateral heads of the gastrocnemius. At the same time, the amplitude and frequency values of EA on the right were higher ($p<0.05$), it was especially marked for the frequency (see Table 3).

Statistical significant correlation coefficients were calculated between the mean values and frequencies of the left and right medial vastus muscles; moderate correlations were found between the mean values of the amplitude of the EA, and loose correlations between the frequency values of the EA (see Table 3). For the lateral head of the gastrocnemius the EA amplitude on the left was slightly higher than on the right, and the frequency on the right was higher than on the left. Moderate correlations were found between the amplitude values of the right and left gastrocnemius muscles; there were either no correlation or weak negative correlation between the medial vastus muscle and the lateral head of the gastrocnemius muscle (for the EA amplitude).

After the workout, the medial vastus muscle had the left EA higher than the right ($p<0.05$) with moderate correlation between the amplitude values. There was more EA on the right than on the left for the calf muscles, and this was strong ($p<0.05$). The moderate correlation between the amplitude values of EA between the medial vastus muscle and the gastrocnemius on the right and left (see Table 3).

Table 2.

The parameters of electrical activity (EA) of musculus vastus lateralis and lateral head of the gastrocnemius (Me [Q1; Q3])

		The parameters of EA	Max. amp., µV	Avg. amp., µV	Avg. freq. 1/s
Before workout	Me [Q1;Q3]	V.L. left	416 [262; 812]	218 [173; 401]	82[42;168]
		V.L. right	902,5[484; 1009]	380,5 [298;489]	124 [68; 180]
		M.G. (*caput laterale)* left	849,5 [502; 992]	347,5 [243; 456]	91[48; 198]
		M.G. (*caput laterale)* right	552 [366; 791]	243,5 [196; 327]	168 [124; 250]
	Value *r*	V.L. left - V.L. right	0,392*	0,351*	0,371*
		M.G. (*caput laterale)* left - M.G. (*caput laterale)* right	0,473*	0,599*	0,468*
		V.L. left - M.G. (*caput laterale)* left	0,180	0,263*	0,302*
		V.L. right - M.G.(*caput laterale)* right	0,385*	0,456*	0,308*
After workout	Me [Q1;Q3]	V.L. left	741,5 [624; 1059]	321,5 [280; 408]	192 [156; 212]
		V.L. right	1087 [890; 1316]	429,5[319; 485]	232 [144; 292]
		M.G. (*caput laterale)* left	903,5 [805; 1023]	392,5 [333; 463]	104 [84; 236]
		M.G. (*caput laterale)* right	639,5 [436; 862]	280,5 [222; 342]	186 [160; 288]
	Value *r*	V.L. left - V.L. right	0,328*	0,117	0,354*
		M.G. (*caput laterale)* left - M.G. (*caput laterale)* right	0,199	0,454*	0,129
		V.L. left - M.G. (*caput laterale)* left	-0,007	-0,219*	0,310*
		V.L. right - M.G. (*caput laterale)* right	0,088	0,196	0,253*

Table 3.

The parameters of electrical activity (EA) of the medial vastus muscle and lateral head of the gastrocnemius (Me [Q1; Q3])

		The parameters of EA	Max. amp., μV	Avg. amp., μV	Avg. freq. 1/s
Before workout	Me [Q1;Q3]	V.M. left	563,5 [411; 953]	282,5 [211; 427]	134 [68; 204]
		V.M. right	643,5 [524; 803]	292 [239; 358]	210 [84; 148]
		M.G. (*caput laterale)* left	617,5 [330; 773]	307 [180; 367]	120 [84; 164]
		M.G. (*caput laterale)* right	478,5[373; 672]	223[198; 284]	136 [88; 179]
	Value *r*	V.M. left - V.M. right	0,158	0,555*	0,263*
		M.G. (*caput laterale)* left - M.G. (*caput laterale)* right	0,319*	0,273*	0,073
		V.M. left - M.G. (*caput laterale)* left	-0,248*	-0,254*	0,185
		V.M. right - M.G.(*caput laterale)* right	-0,242*	-0,095	-0,008
After workout	Me [Q1;Q3]	V.M. left	640 [357; 849]	306 [213; 338]	158 [73; 187]
		V.M. right	522,5 [415; 949]	243,5 [207; 384]	136 [104; 172]
		M.G. (*caput laterale)* left	425 [286; 880]	246 [165; 400]	148 [74; 196]
		M.G. (*caput laterale)* right	832,5 [629; 902]	329 [294; 415]	180 [130; 254]
	Value *r*	V.M. left - V.M. right	0,733*	0,680*	0,697*
		M.G. (*caput laterale)* left - M.G. (*caput laterale)* right	0,309*	0,504*	-0,076
		V.M. left - M.G. (*caput laterale)* left	0,155	0,141	0,306*
		V.M. right - M.G. (*caput laterale)* right	-0,035	-0,189	0,413*
		V.M. left	640 [357; 849]	306 [213; 338]	158 [73; 187]

It is known that the amplitude and frequency characteristics of SEMG reflect the total activity of the motor units involved in the muscular activity [7]. The results of the study show that after the workout the EA registered from the vastus lateralis increased, while the right muscle was more active than the left muscle both before and after the workout. The

EA of calf muscles also increased after training; it was more marked to the right than to the left. The obtained results were consistent with the findings of the involvement of the studied muscles in the implementation of the kicking actions of football players [4].

For the gastrocnemius muscle, varying degrees of EA activation in amplitude and frequency were found, with the result that the left muscles showed higher values of the EA amplitude after training, and the right ones showed higher values of the frequencies.

The results of the correlation analysis made it possible to reveal the presence of moderate positive correlations between the EA of the vastus lateralis and the medial head of the gastrocnemius after exercise. This result can be explained from the point of view of the coactivation phenomenon of the studied muscles, on which is placed greater focus in modern literature [8]. In addition, the gastrocnemius muscle limits extension in the knee joint and at the same time is a synergist of quadriceps in the axial rotation of the tibia and lateral displacement of the knee [9], and the activation of this function probably reflects the result obtained. This assumption, in our opinion, agrees with the description of the kinematic parameters of the knee joint in the step cycle, in which a strong correlation was found between knee flexion and change in the knee setting, as well as the moderate connection between the knee setting and axial rotation [10]. It is also confirmed by the formation of positive moderate correlations in terms of the frequency of EA between the muscle groups under study in all the series of our studies.

The degree of changes in the group of subjects allows us to conclude that this method is highly sensitive to study the functional relationships of various muscles, which can be used to monitor and plan both group and individual training of football players.

CONCLUSIONS

1. The study of the electrical activity of muscles by the method of surface electromyography allows to obtain an objective picture of changes in the electrical activity of muscles and their functional relationships after training, aimed at the development of targeted kicking actions of football players.
2. Workouts aimed at the development of targeted kicking actions of football players contribute not only to the activation of the corresponding muscles (vastus lateralis and gastrocnemius), but also to the formation of functional muscle complexes involved in the axial rotation of the crurae and lateral displacement of the knee.
3. The implementation of physiological control using the method of surface electromyography can be used for effective monitoring and planning of both group and individual training of football players.

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