ORIGINAL ARTICLE

Functional Condition of the Lower Limb Muscles and Their Spinal Centers at the Knee Joint Pathology

A. O. Fedyanin[1], A. A. Shulman[2], I. I. Shaykhutdin[2], A. A. Yeremeyev[1], A. M. Yeremeyev[1]

[1]Department of Human and Animal Physiology, Kazan Federal University, 18 Kremlevskaya str., Kazan, 42008, Russia, [2]Republican Clinical Hospital, 138 Orenburg tract, Kazan, 420064, Russia

Abstract

Aim: The purpose of this work is the research of parameters of electric activity of muscles of a thigh and a shin and functional condition of their spinal centers at healthy subjects and gonarthrosis patients. **Materials and Methods:** By methods of global and electrostimulation myography, we have conducted examination by quadriceps femoris (QFM) and triceps surae at healthy examinees and gonarthrosis patients. **Results:** It is established that pathological process in a knee joint changes a functional condition of the neuromotor apparatus of muscles of the lower limbs. Average amplitude of gonarthrosis was significantly lower than the caused electric activity of these muscles for patients than for healthy examinees. Patients had thresholds of motor (M) and reflex (N) responses higher, and their maximum amplitude as well as the relation of Hmax/Mmax it is much lower. **Conclusion:** Thus, it is established that nociceptive influence from the affected joints slows down the activity of muscles and their spinal centers. Most strongly, these influences are shown on muscles, the extensor participating in direct activity of a joint, i.e. on the QFM, but can affect also other muscles.

Key words: Electrostimulation myography, gonarthrosis, nociceptive impulses, quadriceps femoris, surface electromyography, triceps surae

INTRODUCTION

The deforming arthrosis of a knee joint(gonarthrosis) is the polygenic degenerate and dystrophic disease which brings severe pain and restriction of the movement in a joint. From 13% to 30% of adults suffer from the deforming damages of large joints, and the most frequent localization of pathological process is the knee joint.[1] Such diseases, except medical aspect, have important social and economic value as patients with the deforming arthrosis make about one-third of all persons with permanent disability result of diseases of joints.

It should be noted that, despite a significant amount of the publications devoted to studying arthrosis remain badly investigated disorders of functioning of muscles and their spinal centers at these diseases.

Electromyographic researches of muscles of the lower limbs at diseases of large joints were most often limited to registration spontaneous and randomly the caused activity by means of a surface electromyography method (EMG).[2] There are also numerous researches executed by means of stimulation EMG, the caused motor (M) and reflex (N) responses of triceps surae at various pathologies.[3,4,5] Earlier electromyographic examination of this muscle conducted by us showed that application of stimulation EMG allows to say about a condition of both a peripheral and central link of the neuromotor apparatus[5] that it finally gives the chance to judge the mechanisms which are the cornerstone of change of the activity of muscles with arthrosis.

The purpose of this work is the research of parameters of electric activity of muscles of a thigh and a shin and functional condition of their spinal centers at healthy subjects and gonarthrosis patients.

Address for correspondence:
A. O., Fedyanin, Department of Human and Animal Physiology, Kazan Federal University, 18 Kremlevskaya str., Kazan, 42008, Russia. E-mail: artishock23@gmail.com

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RESEARCH MATERIALS AND METHODS

Twenty-seven healthy examinees of volunteers and 30 patients with a right-hand gonarthrosis from their informed consent were participated in a research. The age of the examined people of a different floor was from 20 to 65 years. At inspection by quadriceps femoris (QFM), examinees were in a prone position on a back and at inspection of triceps surae muscle (TSM) lying on a stomach. All procedures of research are performed with respect for the relevant bioethical standards.

The electric activity (EA) was taken away by means of silver superficial bipolar electrodes with an area of plates of 25 mm^2 from thigh rectus muscle and the medial and lateral heads of the quadriceps muscle (QFM) as well as from a soleus muscle and medial and lateral heads forming triceps surae (TGM). The research was conducted in two modes: At rest and at the maximum muscular contraction. The average amplitude and EA frequency were determined.

The caused electric responses of the surveyed muscles were registered. Electric stimulation was carried out by means of a monopolar superficial electrode. It was placed in projections of femoral and tibial nerves, respectively, in inguinal area (groin area) and a popliteal fossa. The square wave pulses (duration of 1 ms) which were applied once every 10 s were used for stimulation. The stimulus strength varied from 10 to 150 volts. Defined a threshold of emergence (threshold), the latent period (latency), duration (duration) of motor and reflex responses, the relation of the maximum amplitudes of H/M ratio (H/M ratio). For electromyographic testing used research installation on the basis of an electromiograph of "Neurosoft, model MVP-4, Ivanovo" ("Neurosoft" (Neurosoft, model MVP-4, Ivanovo, Russia). The EA parameters registered on the right leg of patients with a right hand gonarthrosis compared to the parameters received on the right leg of healthy examinees. The difference between the EA parameters registered at healthy and sick people was expressed as a percentage and defined the reliability of distinctions by t-criterion of student's *t*-test for in pairs not connected option.

RESULTS

At healthy examinees and gonarthrosis patients, background EA in muscles of a thigh and shin was absent. At any tension of muscles in them, the expressed EA was registered. Average frequency of biopotentials in different heads of the studied muscles significantly did not differ at healthy and sick people and averaged for QFM 202.7 ± 31.8 imp/s and for TGM - 243.7 ± 21.8 imp/s. The minimum EA in thigh QFM as in healthy and sick examinees is found in a direct muscle [Table 1]. At patients, the average amplitude of EA in all heads of QFM was significantly lower than at healthy [Table 1].

The maximum amplitude randomly was registered by the caused EA at healthy examinees in a medial head of TGM [Table 1]. The decrease in amplitude of EA at patients but which was less expressed than in thigh QFM is here too noted, and authentically amplitude decreased only in its medial head [Table 1].

M-responses in TGM at healthy and sick gonarthrosis people arose practically with the identical latent period which averaged 4.4 ± 0.3 ms. Duration of motor responses was also almost identical at all surveyed and on average equaled 11.9 ± 0.7 ms. Healthy examinees have a threshold power of irritation causing that the motor answer was almost identical in all heads and averaged 58.0 ± 4.6 B (V). At gonarthrosis patients, thresholds of the emergence of M-responses were significantly higher and differed in different heads [Figure 1]. M-responses with the maximum amplitude at healthy people are registered in a medial gastrocnemius muscle. At patients, reliable decrease in amplitude of motor responses in all heads of TGM of a shin [Figure 2] is noted.

Reflex responses of TGM of a shin were registered at all surveyed; their latent period equaled on average 27.5 ± 1.1 ms and duration 10.5 ± 1.1 ms. Healthy people had almost identical threshold of the emergence of H-reflexes in different heads and made, on average 62.5 ± 4.3 V.U of patients the threshold of the H-reflexes authentically raised in a soleus muscle and a medial head of TGM [Figure 1]. Reflex responses of the maximum amplitude at all surveys are registered in a lateral head of TGM. At patients, a reliable decrease in amplitude of H-reflexes [Figure 2] is noted. The relation of the maximum amplitude of the H-reflexes to the maximum amplitude of the H/M ratio at healthy examinees differed in different heads of TGM. At patients, a reliable decrease in H/M ratio max was noted in a lateral head of TGM and a soleus muscle [Figure 3].

Table 1: Average amplitude of EA (a) of QFM and TSM in healthy subjects and gonarthrosis patients

Average Amplitude	Healthy	Gonarthrosis	Healthy	Gonarthrosis	Healthy	Gonarthrosis	QFM
A (mV)	Medial heads		Lateral heads		Rectus muscle		
	0.24±0.05	0.09±0.12*	0.26±0.04	0.09±0.02*	0.16±0.02	0.05±0.01*	
A (mV)	Medial heads		Lateral heads		Soleus muscle		TSM
	0.42±0.07	0.20±0.09*	0.20±0.08	0.17±0.03*	0.25±0.18	0.27±0.14*	

EA: Electrical activity, QFM: Quadriceps femoris, TSM: Triceps surae muscle

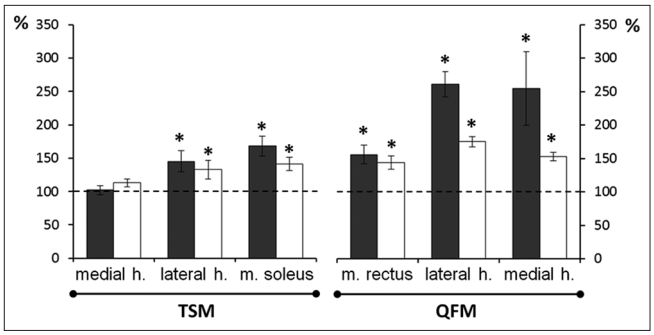

Figure 1: Thresholds of H-and M-responses in patients with gonarthrosis normalized by the values recorded in the healthy (control) subjects. Ordinate axis - threshold of reflex and motor responses, recorded in the triceps surae (medial, lateral heads, and soleus muscle) and the quadriceps femoris (medial, lateral heads, and rectus muscle). Data are shown as a percentage in relation to the control values, taken as of 100%. The black columns - the H-reflex and light - the M-response. TSM - triceps surae muscle, QFM - quadriceps femoris. The dashed line - control. *Reliability, $r < 0.05$

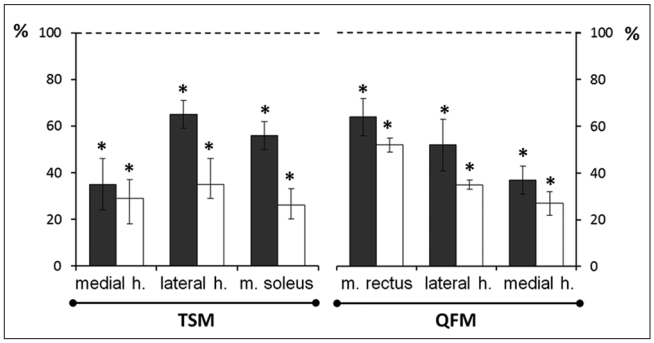

Figure 2: Maximum amplitude of H-and M-responses in patients with gonarthrosis normalized by the values, recorded in the healthy (control) subjects. Ordinate axis - maximum amplitude of reflex and motor responses, recorded in the triceps surae (medial, lateral heads, and soleus muscle) and the quadriceps femoris (medial, lateral heads, and rectus muscle). Other symbols as in Figure 1

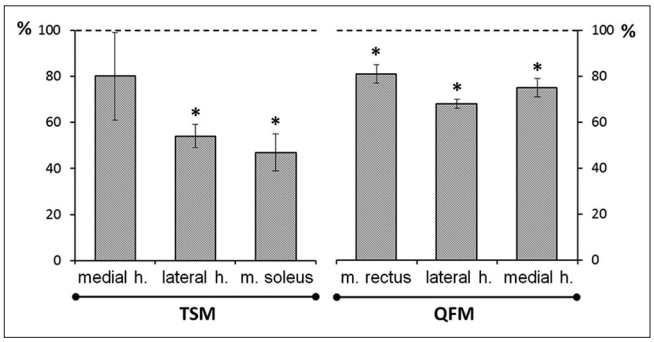

Figure 3: H/M ratio in patients with gonarthrosis normalized by the values, recorded in the healthy (control) subjects. Ordinate axis - H/M ratio, detected in the triceps surae (medial, lateral heads, and soleus muscle) and the quadriceps femoris (medial, lateral heads, and rectus muscle). Other symbols as in Figure 1

At irritation of a femoral nerve in inguinal area in the QFM, motor and reflex responses were also registered. At healthy and sick people, the latent period of emergence of the H/M ratio practically did not differ and in different heads lay ranging from 3.9 ms up to 5.5 ms (on average - 4.7 ± 0.7 ms). Duration of motor responses in different heads of QFM differed slightly and averaged 14.9 ± 1.5 ms. At healthy people, thresholds of the emergence of M-responses in different heads of QFM significantly did not differ and averaged 64.4 ± 6.2 V.U of sick people; the reliable increase in thresholds of the emergence of motor responses which is most expressed in a lateral head of QFM (rice 1) is noted. At healthy people, responses with the maximum amplitude are registered in a medial head of QFM. At patients, the considerable decrease in the amplitude of M-responses which is most expressed in its medial head is noted.

Reflex responses in the four head to a muscle of a shin were registered only at 60% of healthy people and 40% of gonarthrosis patients. The latent period of their emergence averaged 20.2 ± 1.8 ms, i.e. is reliable less than in TGM. Duration of reflex responses was slightly more than in TGM and on average equaled 13.2 ± 1.1 ms ($r > 0.05$).

The threshold of the emergence of reflex responses at healthy people was almost identical quadriceps in all heads and averaged 64.8 ± 5.7 B, i.e., is approximately equal, registered in TGM. At patients, substantial and reliable increase of thresholds of H-reflexes in all heads of QFM with a maximum in lateral is noted [Figure 1]. Reflex responses with the maximum amplitude are registered at healthy people in a direct muscle of a thigh. At gonarthrosis patients, amplitude of H-reflexes decreased in all heads of QFM [Figure 2]. The greatest decrease in amplitude was noted in a medial head of QFM [Figure 2]. Relation of Hmax/Mmax slightly differed in different heads of QFM. Patients in all heads of QFM have a relation of the maximum amplitudes of H/M ratio which was reliable [Figure 3].

DISCUSSION OF RESULTS

The research is any the caused EA in the four-head and showed to triceps surae that it is significantly lower than sick examinees in QFM. Deep articulate pain which practically is always available at the expressed gonarthrosis is similar in the intensity and mechanisms with visceral.[6] It is known that the intensive painful irritation of abdominal organs renders, generally, brake influence on paraspinal muscles of lumbar and abdominal muscles.[7] Apparently, the nociceptive afferentation from the injured joint also has a brake effect on the muscles operating a joint, and this action ambiguously is reflected in different heads of difficult muscles. In the functional relation QFM is a extensor of a shin, TGM is involved in the management of a knee joint much to a lesser extent and can provide its bending. Our results show that

the braking caused by nociceptive irritation affects stronger muscles which in the functional relation are more closely tied with the affected joint and are its extensors.

The research of motor (M) and reflex (N) responses of muscles gives the chance to judge as a condition of a peripheral link of the neuromotor apparatus and a condition of the spinal centers.[5,8] A classical object of a research of monosynaptic of reflex responses is the triceps surae. Definition of thresholds of the emergence of H-reflexes and their maximum amplitude allows to define reflex excitability of lumbosacral motoneurons,[9] and the same parameters of the H/M ratio give the chance to judge a condition of the muscle.[10] As we already noted, the quadriceps muscle in this regard is almost not investigated. Meanwhile, this muscle is involved in work of knee and coxofemoral joints. It was revealed that M-responses in different heads of QFM are registered at all examined people. Reflex responses are registered not at all examinees that are probably connected with more expressed brake influences on motor-neurons, the innervating QFM from supraspinal structures. At healthy people, thresholds of the emergence of M-responses in different heads of triceps surae significantly did not differ, and responses with the maximum amplitude are registered in a medial head of TGM. Gonarthrosis patients (except for a medial head of TGM) had thresholds of M-responses authentically above, and their maximum amplitude in all heads of TGM was authentically below. Therefore, inflammatory process in a knee joint slows down activity of all heads of TGM, influencing parameters of electric muscular responses. Giving an assessment of a condition of a peripheral link of the motive device in this case, it is probably better to use the maximum amplitude of motor responses as thresholds of their emergence are rather variable and depend on a depth of a tibial nerve and the correct arrangement of the irritating electrode.

Reflex responses are registered in all heads of TGM both at healthy people and gonarthrosis patients. Patients had thresholds of the emergence of H-reflexes authentically above, and their maximum amplitude is lower than at healthy examinees. The relation of the maximum amplitudes of reflex and motor responses which speaks about a share reflex of the excited motor neurons[11] at patients is reliable below. All this demonstrates that the painful impulsation from the affected joint brakes the reflex excitability of a motor kernel of TGM. Besides at pathology of joints of the lower limbs, development of their ischemia and ischemia of the corresponding nerves is possible. Hence, in the work of Zakutansky *et al*.,[12] it was shown that sharp ischemia of peripheral axons causes a decrease in amplitude of H-reflexes of a soleus muscle.

At healthy people, thresholds of the emergence of M-responses in all surveyed heads of QFM were approximately identical and did not differ authentically from that, registered in TGM. Patients had a reliable increase in thresholds of motor responses. It can be connected with a decrease in excitability of efferent and with more expressed brake influence of a painful afferentation on motor neurons, innervating these muscles. Healthy people had a maximum amplitude of motor responses of QFM authentically above than at patients. Thus, inflammation of knee joint causes the protective braking of contraction activity by the quadriceps which is most expressed for its medial head. The registered changes of parameters of M-responses in all surveyed muscles at patients with gonarthrosis are probably caused by the desynchronization of categories of motive units caused by nociceptive influence from the injured joint. Besides, it can be connected with the developing atrophy of muscles.[13]

Reflex responses of QFM at gonarthrosis patients are registered by 1.5 times less than at healthy people, thresholds of their emergence are higher, and the maximum amplitude is lower (the most considerable effect is noted in a medial head of QFM). All these are probably connected with the fact that to already available expressed supraspinal braking of a motor kernel of this muscle, brake influence from a zone of the inflamed joint joins. About the same reduction of the relation of the maximum amplitudes of M - and H-reflexes testifies. The braking effect on motor neuron pool of both QFM and TGM can be carried out through the system of afferent of a flexors reflex.[8] Besides, thin afferent fibers on which the nociceptive impulses come to a spinal cord can render presynaptic braking on presynaptic inhibition of the IA afferents, a monosynaptic connected with the motor-neurons innervating these muscles.[8,14]

CONCLUSION

The received results show that nociceptive influence from a zone of the inflamed knee joint has brake character and, in a varying degree, affects a functional condition of all links of the neuromotor apparatus of all muscles which are near it irrespective of their participation in the activity of a joint. Of course, this braking effect is the strongest, it is shown on muscles which in the functional relation are more closely tied with the articulate movements. Such protective braking is shown both on activities of the muscle and on a condition of its spinal centers. At early stages of development of a disease when its obvious symptoms are expressed slightly, inspection by all quadriceps of a thigh (and it is possible, only its medial head) and (or) any of heads of triceps surae by the methods of a global and electrostimulation myography can serve as additional diagnostic reception of identification of gonarthrosis. Thus, at treatment of arthrosis of large joints, correction of violations of the functioning of the neuromuscular device as at the peripheral and central levels is necessary.

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