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CHANGES IN EMG AND H-REFLEX CHARACTERISTICS OF KNEE FLEXOR MUSCLES FOR ATHLETES UNDER THE INFLUENCE OF CENTRAL NEURAL REGULATION

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Abstract

Applied kinesiology (AK) diagnostic test is a manual muscle testing and technique widely used within the Integrative Medical community by sports doctors and sports physiotherapists. Empirically defined functionally weak muscles are the cause of a particular dysfunction of the organism, but it is not clear if there are physiological findings. Objective: Does a functionally altered state of central neural regulation (CNR) affect H-reflex and EMG characteristics? Material and methods: 34 (16 H-reflex measurements and 18 EMG measurements) healthy LASE students, 21± 0.3 years old, average height - 174 ± 2 cm and the average weight – 63±2 kg, was performed EMG and H-reflex measurements in normal and altered CNR functional states was done on the muscles of the gastrocnemius (GM) and biceps femoris (BF). Results: statistically significant changes (p<.05; .01) are observed in EMG and H-reflex characteristics in normal and altered CNR functional states. Conclusion: there are tendencies that a qualitatively assessed CNR condition can be assessed by quantitative measurements. The groups have a small number of participants, so research in this field should be continued.

Keywords: *applied kinesiology, normal and altered central neural regulation, functional state, EMG, H-reflex.*

Introduction

Due to technical possibilities, neurophysiologists have started to focus on the analysis of neural modelling of movement control and its relation to the quality of movement. Mainly, the influence of the pathological conditions (stroke, CNS trauma, etc.) of the central nervous system's (CNS) structures on the motor control of movement is analysed, but the studies should continue adaptability of movement organization models when changes are experienced in the somatic or autonomic structures of the organism. In experimental studies, the Applied kinesiology (AK) method is empirically defined as the influence of the functional changes in various body structures on neuromuscular regulation of muscles, leading to functional changes in movement organization models (Walther, 2000; Frost, 2002).

AK tests are increasingly applied as a functional diagnostic tool in the training process involving sports doctors and sports physiotherapists. Empirically defined functionally weak muscle are the cause of a particular dysfunction of the organism (Walther, 2000). It is not clear, whether prevention of the functional weakness of a particular muscle will directly affect the identified organism's dysfunction or adaptive changes will take place in the organism impacting the specific dysfunction. The explanation of such correlations allows using the AK methods in a more purposeful way to improve the functional abilities of the athletes' body.

In AK, a diagnostic test is a manual muscle testing and technique widely used within the Integrative Medical community (Schwartz et al., 2014). The research object of AK is the functional (dynamic) neurology (Goodheart, 1964 - 1998, 1998; Schmitt, Yanuck, 1991). Changes during a muscle test are related to changes in the central or peripheral nervous system, but the treatment is effective only if it is focused on the exact neural disorder (Schmitt, Yanuck, 1991).

To control the functional state of a particular muscle, the organization of movements and dynamic anatomy of the joint must be strictly observed. The examination of the muscles involved in the action of the joint must be carried out with the joint in a precisely fixed position, i.e., in the appropriate angle at which the muscle acts as an agonist. The vector of the counteraction force applied by the examiner must be directed in a precisely defined direction for the active fibres of the test muscle would function, creating an optimal force vector in the physiological mode corresponding to the movement being tested (Schwartz et al., 2014).

Many scientific publication results show the usefulness of AK method in relation to various illnesses of the body systems and options for their treatment - joint dysfunctions, lymphatic system disorders, circulatory system disorders in a muscle or related organ, mineral or vitamin deficiency or overdose, disturbed balance in the meridian system, abnormalities in the digestive system, psycho-emotional stress – these are factors that can lead to formation of a functionally weak muscle (Walther, 2002; Jensen, 2015). All these systems are mutually interconnected and affect each other (Frost, 2002). It can be concluded that this method is adopted as empirically good qualitative method for diagnostics, but little is known about the changes of quantitatively measurable physiological parameters and their effectiveness for assessing various body systems to make conclusions on dysfunctions of neural regulation.

For this study, the author has chosen empirically measurable parameters as the H-reflex and EMG characteristics and a qualitative evaluation criterion – the functional changes in the CNR system assessed by AK method to obtain the information about the muscle: is the muscle normal or functionally weak tested.

The functional changes in CNR may vary – starting from the cerebral cortex torsion and ending with the stroke. In this article, by using the term "muscle with altered central neural regulation" (CNR), the author means the activity of the muscle with functional dysfunctions.

Materials and Methods

Participants. The group of research participants consisted of 34 (16 H-reflex measurements and 18 EMG measurements) practically healthy Latvian Academy of Sports Education (LASE) 2nd and 3rd year full-time physiotherapy students, who are physically active on amateur level, from which the research sample was selected, and the number of participants varied in each stage of research. The average age of participants was 21± 0.3 years, average height – 174 ± 2cm and the average weight – 63±2kg.

The organization of the study took place in several stages, and the students from LASE master's and physiotherapy bachelor's study programmes were also involved in organization and implementation of the study. The diagnostic experiment stages for the article took place from October 2015 to November 2016.

Prior to each research stage, the participants were introduced with the research routine and conditions, the information about data usage, storage and confidentiality was explained, as well as about the possibility to terminate their participation in the research study at any time. Each participant gave his/her consent to voluntary participation in the research. The author asked participants certain questions to determine the inclusion/exclusion criteria. The research was conducted in accordance with the norms of the Ethical Commission of LASE and the local institutions, and permission was obtained.

Prior to each measurement, the research subject had to answer the questions related to the exclusion criteria. If a participant did not mark any of the exclusion criteria, the measurements could take place. Thus, participants were included or excluded in this study according to certain criteria. *Inclusion criteria:* functionally normal neuromuscular regulation (functionally strong) in GM; appropriate age; physically active lifestyle - engages in regular sports activities at least 2 times a week; motivation to expose oneself to physical activity; motivation to expose oneself to the effects of electrical stimulation. *Exclusion criteria:* no GM reflex response to epigastric irritation; muscle pain; edema; diseases or complaints of peripheral blood regulation; radiologically diagnosed diseases of the spine with effects on neurological structures; problems of organizing and managing movements; acute or chronic CNS diseases (including mental illness); knee disease or injury; alcohol or other intoxicants have been used in the last 72h; the last 72h has been a high-intensity or high-volume load (strength load, hypertrophy training, high-intensity interval training, etc.); Feeling sick (nausea) or being sick (vomiting) on the epigastric region; acute or chronic diseases of the internal organs (gastritis in the acute or subacute phase, gastric ulcer, inflammation of the duodenum, diseases of the pancreas, liver or gallbladder, irritable bowel syndrome, etc.).

For each participant, the tests were performed in five states (resting before the test, isometric load at 60 degrees in the knee joint, maximum voluntary isometric contraction (MVIC), isometric contraction with 5% load from the MVIC at 60 degrees in the knee joint, after the test) for the EMG measurements and two (BEFORE 1&2 and POSITION 1&3) for the H-reflex with two different qualitatively observed functional states of CNR. Schematically it is shown in Fig.1.

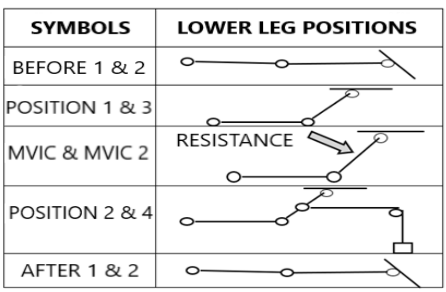


Figure 1. Lower leg positions and symbols during tests

In all research phases, when the load measurements were taken, a standardized testing position was used – lying on the stomach with the knee flexed in 60 degrees, as in this position. In turn, the indicators of muscle tone and electrical activity at resting position were obtained with the participant lying on his/her stomach. For the plantar flexion of the foot not to affect the muscle tension, the front part of the ankle joint rested on an elevation with a diameter of 15cm. Schematic representation of the research tests can see in Fig.2.

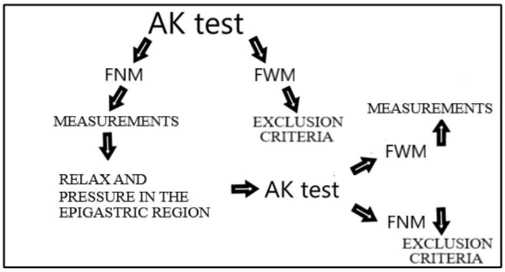


Figure 2. Schematic representation of the research tests

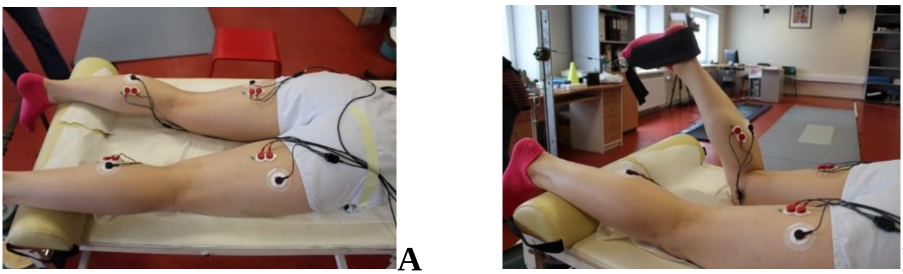
Applied kinesiology (AK) manual muscle testing. In the test when lying on the stomach, the examiner bends the patient's leg in a 60-degree flexion at the knee joint and asks the patient to perform a plantar flexion at the ankle joint. The examiner places one hand on the patient's pelvis, fixing it, and another hand on the distal part of the lower leg. The test takes place, when a participant performs a lower leg flexion, but examiner – resistance in the direction of extension. The therapist maintains resistance for three seconds against the research participant's isometric flexion and performs small amplitudes, but a sharp lower leg extension. If the myotatic reflex immediately appears in a muscle, the muscle is considered normal (FNM), in turn, if the myotatic reflex does not immediately appear in the muscle, the muscle is considered as functionally weak (FWM) or with altered neural regulation - following the findings of the authors of the AK method (Goodheart, 1964 - 1998, 1998; Schmitt, Yanuck, 1991, Walther, 2000; Frost, 2002; Schwartz et al., 2014; Jensen, 2015). Additional activities, such lifting the pelvis, seizures in *hamstring* muscles, are also considered as signs of a functionally weak GM.

To induce functional disturbances in CNR, a hard ball of rubber material was left in the epigastric region, i.e., against the abdominal cavity below the ribs on the left side, which created pressure. Following this irritation, functional disorders in CNR were induced and GM remained functionally weak. It should be noted that these are functional disorders and have no lasting consequences.

Dynamometry. The method was used to determine the static maximum forces of knee flexors, i.e., MVIC for the muscle with a normal and altered CNR before EMG characteristics to calculate 5% load. We used manual dynamometer *Lafayette Instrument Model: 01165 Manual Muscle Tester* (*Lafayette Instrument, Ltd.*, U.K.) for measuring the static force. Test was performed on standard position on the stomach. The dynamometer is placed against the heel bone. The respondent performs the flexion of the lower leg in the knee joint, but the physiotherapist, to ensure the static contraction, fixes the lower leg keeping the dynamometer and the lower leg still for three seconds after which the result is read (Kendall et al., 1952; Kendall et al., 2005). Three repetitions were performed, and the best result was recorded. The pause between measurements was 20 seconds. The result is read in kilograms to calculate the load at test POSITIONS 2 and 4.

EMG and Electrostimulation. Electromyography (EMG) is a technique for recording the biopotential of skeletal muscles with an electromyograph. The electrical activity of GM was measured by placing the electrode on the medial belly of the muscle and BF muscle.

To measure EMG on both muscles (see Fig.3A & 3B) and H-reflex (see Fig.4) of the GM, a 16 channel EMG telemetry system ME6000 (Mega Electronics Ltd., Kuopio, Finland) was used with standard bipolar electrodes (Noraxon, USA). The electrodes were placed on the medial belly of GM and the long head of BF. EMG activity was registered after 10-second interval with two functionally different states of CNR. Root Mean Square (RMS) was assessed from EMG characteristics.



A B

Figure 3. EMG test positions and electrode placement on muscle: A-rest BEFORE; B - in test position POSITIONS 2 and 4 (60-degree flexion of the lower leg in the knee joint with 5% load of MVIC) (photo from the author's archive)

Electrostimulation is an electric stimulation of a peripheral nerve with pulsed direct current. The electrical stimulation signal spreads through the nerve both efferently and afferently. The efferent wave causes an immediate muscle contraction with a corresponding M signal wave, but the afferent signal, passing through the spinal cord segment, returns to the muscle, causing repeated muscle contraction, which is recorded (EMG) as H-reflex of biopotential, about 28-35 ms after stimulation. The H-reflex, both in terms of a time lag and amplitude, characterizes the quality of the reflex circle (*Burke*, 2016).

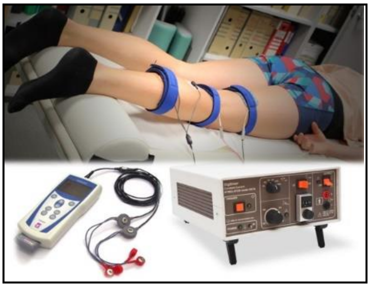


Figure 4. Electrostimulation of the popliteus nerve by measuring the H-reflex at rest with EMG (photo from the author's archive*)*

To measure the H-reflex, 20-40V strong and 1ms long once-only current wave impulses were performed, using electrostimulator *Digitimer* (Digitimer, Ltd., UK). An electrode was placed under the knee to stimulate *n. popliteus,* but the surface electrode of electromyography was placed on medial belly of GM to record the biopotential changes. This method with various protocols has been described in several scientific publications (Thompson et al., 2009; Groisman et al., 2014; Burke, 2016). The electrostimulation was performed for research participants both with and without CNR functional disorders.

Data analysis. The processing of data obtained in research experiments was calculated with "Microsoft Office Excel" program and mathematical data processing computer program "SPSS". This method analyses the interaction of two proportionally dependent factors. A Mann-Whitney U test was used for comparison of two samples (data not normally distributed). It was determined the samples are statistically different at different levels (p<.05; .01). The standard error of the results of the research participants and the homogeneity of the group results – the coefficient of variation of the results were evaluated by the methods of mathematical statistics.

Results

Impact of changes in CNR on knee flexors EMG characteristics. Analysing the group's overall results of GM and BF, the statistically significant differences can be observed in several cases, but it should be noted that the results data not normally distributed. Applying inclusion and exclusion criteria and grouping young healthy athletes by age and CNR functional state, the results suggest that adaptation of the organism to CNR irritation may be multifactorial and the search for a linear relationship may be insufficient. Clearly demonstrated by the results – they can be divided into three groups: the RMS activity 1) increase; 2) not change; 3) decrease.

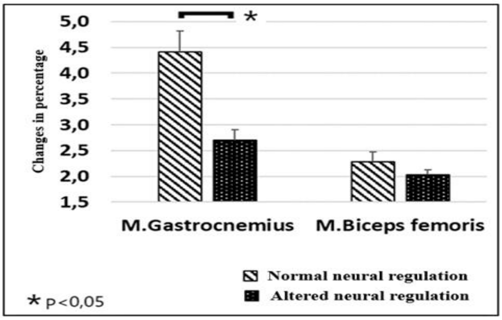


Figure 5. Changes in group's RMS results in lower leg flexor muscles at rest before test (BEFORE 1 and 2).

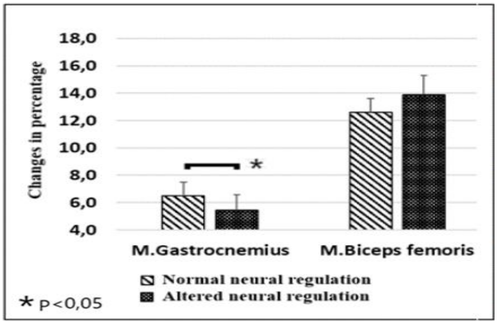


Figure 6. Changes in group's RMS results in lower leg flexor muscles at knee flexion of 60° (POSITION 1 and 3)

Analysing the group's mean results shows significant differences in the following EMG characteristics: in GM testing positions BEFORE 1 and 2 (p<0.05), POSITION 1 and 3 (p<0.05), MVIC 1 and 2 (p<0.01), and AFTER 1 and 2 (p<0.01); in the BF at testing position MVIC 1 and 2 (p<0.05). The results can be viewed in Figure 5., 6., 7., 8., 9.

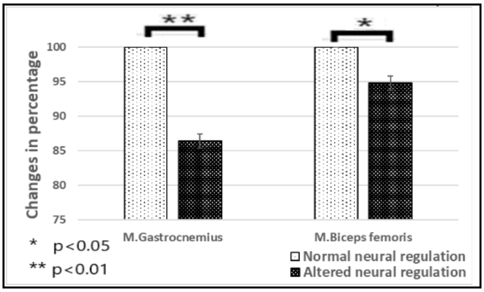


Figure 7. Changes in group's RMS activity results in lower leg flexor muscles at knee flexion of 60° (MVIC 1 and 2)

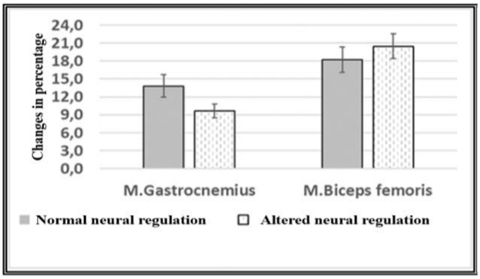


Figure 8. Changes in group's RMS activity results in lower leg flexor muscles at knee flexion of 60° with 5% load from MVIC

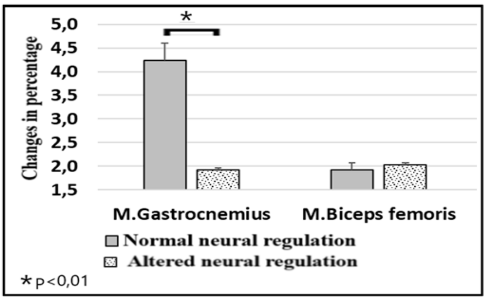


Figure 9. Changes in group's RMS activity results in lower leg flexor muscles at rest after the load (AFTER 1 and 2)

Impact of changes in CNR on GM H-reflex. At rest (BEFORE 1 and 2), statistically significant (p <0.01) differences can be observed in GM. H-reflex activity with altered CNR is 58.1±8.4% in comparison to the muscle with normal CNR. The results can be viewed in Figure 10.

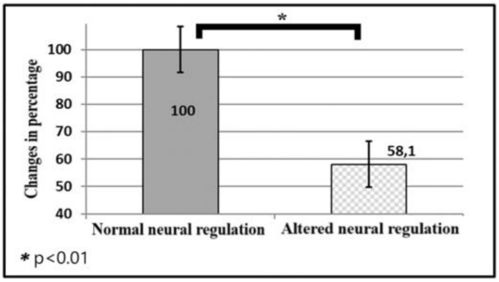


Figure 10. Changes in group's H-reflex mean results on gastrocnemius muscle at rest (BEFORE 1 and 2)

Analysing the group's mean results of the knee at 60° flexion (POSITION 1 and 3) with normal and altered CNR, not statistically significant ($p > 0.05$) differences were found.

Discussion

Analysing the obtained mean data in all researched positions, a large dispersion of parameter results can be observed – the variation coefficient >10%. This indicates that the results presented by the subjects are very different and that is why the dispersion is so large in the group. For several parameters the neuromuscular regulation functional disorders are manifested either as a decrease, or remain unchanged, or as an increase of the characteristics.

This may suggest that the adaptive mechanisms for CNR functional disorders are not unambiguous. This fact again indicates that the impact of CNR functional disorders on the functional activity of the studied muscle is not linearly causal, but different mechanisms may be involved in the adaptation process. It corresponds with the findings of several authors (Васильева, 1999(a)); Frost, 2002; Ramšak, Gerz, 2005; Myers, 2014), who have indicated that the functional weakness of muscle can occur if there are local and segmental, visceral, endocrine, or psychological disorders in a connective tissue network. In such cases, it is more useful to analyse the reaction types of each individual and, if possible, to group the individuals according to them.

Generation of mechanical pressure in epigastric region, causing the functional CNR disorder of GM, mostly influences the tissues in left side under the ribs, creates a mechanical irritation for the place where diaphragm is attached to ribs, also causes irritation of colon segment fascia and, possibly, the stretch of pancreatic fascia (Standring, 2015). In any case, it causes neural regulation functional disorders of GM, which also manifest itself in the decreased H-reflex and various changes of adaptation mechanism in muscle EMG. As published above blood circulation redistribution disorders in the lower leg muscles (Gavrona et al., 2015), as well as in various changes of adaptation mechanism in muscle tonus indicators (Varpa et al., 2016) can be identified.

Rosner (Rosner, 2012) writes that a functionally weak muscle will cause changes in the adaptive processes both locally, segmentally, as well as for the system, but the problem is in the fact that it is not correct to compare such individual CNR functional disorders with average values of quantitative parameters of any group studied. In such cases, the nature of the adaptive changes of each individual parameter is lost as well as the direct link to the CNR functional disorders.

Analysing the EMG activity results obtained by the author, the changes for participants mainly take place in two directions – RMS results in the muscles either decrease or increase, which indicates that the body as a system is trying to adapt to the stimuli. Which way will it happen – it is difficult to predict, therefore each subject's individual adaptability should be researched in-depth to clarify under the influence of which body system it takes? The distribution of fibres in the muscle bundle works differently, and the muscle activation of the researched subject will depend on several factors, which must be kept in mind when evaluating the mean results. In this study the author used the surface electrodes, which provide information on electrical activity generated by muscle biopotentials, which has reached the surface of the body with EMG surface electrodes, obtaining interference signals of all different biopotential impulses of heterogeneously distributed muscle fibres. Therefore, a Fourier analysis was employed, which leads to the conclusion that the obtained data demonstrate the electrical activity changes of different tissues and their layers – not only of muscle tissue (Novotny, Sedlacek, 2008; Vieira et al., 2017). According to the findings of this study, if there are qualitative changes in the muscle – changes that are perceptible by therapist's hand, then the quantitative measurements of respondents need to be grouped in accordance with the reaction types, and only then it is possible to compare it with the muscle that has normal CNR. In this case it is not correct to expect linear cause-and-effect changes in the group results, because the muscle CNR system is not subject to the following correlations.

Studying changes in H-reflex activity in a muscle with normal and altered CNR, there is a significant difference between the testing positions. If in the resting position all participants experience a decrease in H-reflex activity, then in the 60° of knee flexion during low-intensity aerobic loading three different adaptation types can be observed for the participants: activity decreases, activity increases, and activity remains unchanged. Looking at various H-reflex research studies in scientific databases, it can be observed that most of them are on the impact of central and peripheral nervous system on H-reflex in various trauma/post-trauma cases related to the functional state of peripheral nervous system (Burke, 2016; Andrewsa et al., 2016; Mitsuyama et al., 2016). In the context of this study, this does not provide sufficient information on changes in H-reflex quality under the influence of CNR changes, because all participants of this research were practically healthy people who do not have a history of injuries or pain, besides, they were students of LASE, enthusiasts of active lifestyle, and athletes. There are studies on changes in H-reflex under the influence of alcohol consumption, which could change the mechanisms of the central regulatory system. In such cases, alcohol affected H-reflex activity by reducing it (Cho et al., 2013).

In this study, a discomfort was created for research participants with a small solid ball in epigastric region, changing the myotatic reflex of knee flexor muscles, which then where observed using a qualitative testing method, after which it was assumed that the CNR of the muscle was disturbed on subcortical level of central nervous system, and the movement execution was carried over to the cortical level, as described by various authors (Lundy-Ekman, 1998; Frost, 2002; Hochman, 2007). This means that a muscle or a group of muscles works at a conscious CNS level, and in such cases the research studies do not unequivocally indicate a decrease in functionally weak muscle strength (Cuthbert, Goodheart, 2007; Schwartz et al., 2014). It must be noted that all the changes, that research participants had in resting position and which occurred as decrease of the reflex, possibly can be explained with the fact that such testing position does not require muscle contraction in conscious (cortical) level, and it mainly takes place in subcortical level, but, keeping the lower leg in testing POSITION 1 and 3, the motor control mechanisms were required, which strongly involve the level of consciousness. As recognized by Lundy-Ekman (Lundy-Ekman, 1998) and Hochman (Hochman, 2007), the nerve impulse, in this case under electrostimulation of popliteus nerve, does not stop at the level of reflex arc, but afferently goes to CNS level, and on its way there are very many synapses including also from the organs, which have a reflectory connection to a specific muscle (Goodheart, 1964-1998, 1998; Scoop,1979; Васильева, 1996; Carpenter et al., 1997; Ramšak, Gerz, 2005; Conable, 2010), then, by causing stimuli with a small solid ball and influencing the body's homeostasis, which causes the altered neural regulation of the muscle, it was achieved that the body must use other regulatory mechanisms in order to deal with the load imposed. During the low intensity aerobic exercises, three different variants of the changes of H-reflex results can be observed. This fact must be remembered by sports professionals, especially in sports where the stretching reflex is needed for performing fast, accurate movements. The results indicate that the adaptation of the organism is not developed by linear correlations, and further studies are needed on which adaptation mechanisms get activated in each individual case.

In general, the author emphasizes that the adaptation of the organism to a specific state takes place multifactorial, i.e., adaptation to external influences is realized in very different ways, depending on everyone's activities of potential regulatory functions (and they are very many). Therefore, to look for one cause-and-effect chain would not be logical. With a greater or lesser probability, it is only possible to talk about the relationship of subjective empirical results with quantitative measurements of physiological parameters for everyone separately. Also, there is a need for a larger research group for more significant results.

The author repeatedly concludes that adaptation takes place throughout the body and is nonlinear and multifactorial. The author Siliņš (Siliņš, 2008) formulates it as a system that operates within the framework of a determined chaos. This means that when changing any parameter and judging by the chaotic nature of regulation, the changes will not always be in the direction as planned, but judging by the determined nature of regulation, there are certain possibilities for the system to adapt to the irritation caused.

Conclusions

1. Statistically significant ($P<0.05$) changes in EMG results are at different test positions with normal and altered CNR on GM and BF muscles ($p<.05$; .01). The data are not a normally distributed because the types of CNR ablation do not form linear relationships. The groups have a small number of participants, so research in this field should be continued.
2. The impact of changes in CNR on GM H-reflex, in group's mean results statistically significant ($p<0.05$) differences were observed in rest position. Changes in the quantitative parameters with normal and altered state of CNR in GM under the aerobic load and on rest are different, indicating that the adaptation of the body system is not linear in one direction and that the changes depend on self-regulatory systems.

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