BioNanoSci. (2016) 6:368–369
DOI 10.1007/s12668-016-0231-z

Effect of Gravitational Unloading on Rat's Gastrocnemius Muscle Spinal Motor Center

Anton Eremeev[1] · **Tatyana Baltina**[1] · **Artur Fedyanin**[1] · **Alexandr Eremeev**[1] · **Igor Lavrov**[1]

Published online: 19 August 2016

Abstract The electromyographic methods were performed to estimate the rat's gastrocnemius muscle spinal motor center functional state under conditions of gravity unloading. The research was performed in the following experimental series: (1) after 35 days of microgravity influence; (2) after 35 days of microgravity influence in combination with support receptor excitation. The series of experiments showed that parameters of recorded evoked potentials in gastrocnemius muscle (GM) induced by sciatic nerve stimulation while gravity unloading (group 1), significantly differed from those registered in intact animals and not differed in group 2. It has been demonstrated that the reflex excitability of rat's gastrocnemius muscle spinal motor center increases under conditions of gravity unloading. Support afferentation limitation plays the key role in motor centers state change.

Keywords Gravitational unloading · Motor center · Support afferentation · Electromyography

1 Introduction

Gravity is recognized as one of the most significant physical agents in animal and human functional systems evolution and particularly in locomotor apparatus evolution.

The integral qualities (strength, efficiency) of muscular system and single muscle groups significantly have been changing under conditions of gravity limitation as well as basic characteristics (tension, dimensions, structure of contractile apparatus, and its energy potential) [1]. It is known to a large extent that characteristics of locomotor apparatus peripheral part are determined by motor centers condition. However, the strategies of locomotion control under motor disorders and/or motor limitation are not investigated sufficiently. The discussion about factors that could trigger functional state of neuromotor system changes under such conditions takes place. The answers on these questions seem essential for compensatory-recovering reorganization of motor control deeper understanding and implementation of suitable approaches for efficiency increase of such techniques.

The purpose of the study was to estimate the rat's gastrocnemius muscle (GM) motor center functional state under conditions of gravity unloading.

2 Material and Methods

The experiments were performed on 19 laboratory male rats of line Wistar weighing 130–150 g. Functional state of rats GM motor center was estimated in the following experimental series: (1) after 35 days of microgravity influence ($n = 7$); (2) after 35 days of microgravity influence in combination with support receptor excitation ($n = 7$). The gravity unloading was modeled using rats suspension in antiorthostatic position (head-down position) [2, 3]. The support zone of rats hindlimbs was stimulated daily. The stimulation continued for 20 min per hour (for 4 h), amplitude averaged 0.5 mm, frequency—50 Hz.

Anton Eremeev, Tatyana Baltina, Artur Fedyanin, Alexandr Eremeev and Igor Lavrov contributed equally to this work.

✉ Anton Eremeev
2Anton.Eremeev@mail.ru

[1] Department of Human and Animal Physiology, Institute of Fundamental Medicine and Biology, Kazan Federal University, Kremlevskaya 18, Kazan 420008, Russia

The electric responses of GM induced by stimulation of sciatic nerve with single rectangular impulse (duration of 0.5 ms, frequency of 0.5 impulses per minute) were registered. Impulse intensity varied from 0.3 to 30 V. The original research equipment described in previous publications was used [4]. Spinal motoneurons excitability was estimated by means of H-response (reflex response) monosynaptic test. The threshold and the maximum amplitude of evoked potentials were quantified. Also, the M-response (motor response) was registered. The ratio of maximum amplitudes of H and M-responses was calculated. The group of intact animals was used as the control one ($n = 5$). The significant differences were determined by Student's t test. The experimental data were expressed as percentage of data calculated in group of intact animals and taken as 100 %.

All the procedures was conducted in accordance with Declaration of Helsinki (1975) and approved by Kazan University Bioethical Committee.

3 Results and Discussion

The series of experiments showed that parameters of recorded evoked potentials in GM induced by sciatic nerve stimulation while gravity unloading (group 1) significantly differed from those registered in intact animals. The threshold of rats' GM reflex response in group 1 averaged 47.0 ± 9.5 % ($p < 0.05$), amplitude averaged 154.6 ± 15.2 % ($p < 0.05$), ratio of maximum amplitudes of H and M-responses—123 ± 7 % ($p < 0.05$) comparing to control.

H-response modulates monosynaptic conduction of signals through CNS which are important for locomotor function realization and used for spinal motoneurons reflex irritability estimation [5]. The ratio of maximum amplitudes of H and M-responses is believed to be an accurate marker demonstrating the quantity of alpha-motoneurons activated by afferent stimulation [6]. The data received in our experiments shows the increase of reflex excitability of GM motor center motoneurons, motoneurons pool increase which is responding to stimulation and subthreshold line constriction. The support sensibility defect which is known to play a key role in motor control could be regarded as possible cause of gravity unloading effects. Namely, it has been demonstrated that step afferentation could act as a trigger in system of postural reactions [1].

The series of experiments combining gravity unloading and support receptors stimulation were performed for investigation of the hypothesis (group 2).

Electromyographic characteristics recorded in such experimental conditions differed from those that were found in animals during the antiorthostatic suspending (without support afferentation activation) and were close to control data. So, the H-response threshold averaged 87 ± 10 % ($p > 0.05$), amplitude—105 ± 15 % ($p > 0.05$), ratio of maximum amplitudes of H and M-responses—102 ± 7 % comparing with data recorded in intact animals. Received material corresponds with the data in literature: changes in skeletal muscles under conditions of hypogravity are limited or prevented by foot support zones mechanical stimulation [7, 8].

4 Conclusions

Thus, the rat's GM spinal motor center reflex excitability determined by H-response characteristics under conditions of gravity unloading increase. Limitation of support afferentation plays a key role in motor centers condition change.

Acknowledgments This work was supported by RSF, research project no. 15-15-20036, partially supported by RFBR, research project no. 15-04-05951a.

References

1. Grigoriev, A. I., Kozlovskaya, I. B., Shenkman, B. S. (2004). The role of support afferents in organisation of the tonic muscle system. *Rossiĭskii Fiziologicheskiĭ Zhurnal Imeni I.M. Sechenova, 9*(5), 508–521.
2. Ilyin, E. A., & Novikov, V. E. (1980). Stand for modelling the physiological effects of weightlessness in laboratory experiments with rats. *Kosmicheskaya biologiya i aviakosmicheskaya meditsina, 24*(3), 79–80.
3. Morey-Holton, E. R., & Globus, R. K. (2002). Hindlimb unloading rodent model: technical aspects. *Journal of Applied Physiology, 92*, 1367–1377.
4. Eremeev, A. A., Chebotarev, M. A., Kuznetsov, M. V., Baltin, M. E., Shenkman, B. S. (2015). Neuromotor apparatus in the condition of gravitational unloading: central and peripheral effects. *Aviakosmicheskaia i Ekologicheskaia Meditsina, 49*(1), 32–36.
5. Cho, S. H., & Lee, J. H. (2013). Comparison of the amplitudes of the H-reflex of post-stroke hemiplegia patients and normal adults during walking. *Journal of Physical Therapy Science, 25*(6), 729–732.
6. Pensini, M., & Martin, A. (2004). Effect of voluntary contraction intensity on the H-reflex and V-wave response. *Neuroscience Letters, 367*, 369–374.
7. Shenkman, B. S., Podlubnaya, Z. A., Vikhlyantsev, I. M., et al. (2004). Human soleus fibers contractile characteristics and sarcomeric cytoskeletal proteins after gravitational unloading. Contribution of support stimulus. *Biofizika, 49*(5), 881–890.
8. Miller, T. F., Saenko, I. V., Popov, D. V., Vinogradova, O. L., Kozlovskaya, I. B. (2004). Effect of mechanical stimulation of the support zones of soles on the muscle stiffness in 7-day dry immersion. *Journal of Gravitational Physiology, 11*(2), 135–136.