УДК 611.018.86:612.824
ББК 75.0

Sergii Popel, Bogdan Mytskan

THE STRUCTURE OF SKELETAL MUSCLE AFTER HYPOKINESIA AND PHYSICAL TRAINING OF THE AVERAGE AEROBIC CAPACITY

В умовах морфологічного експерименту досліджували скелетні м'язи лабораторних щурів в умовах тривалої гіпокінезії і подальшого фізичного навантаження середньої аеробної потужності.

Досліди проводилися на 125 щурах з масою тіла 120–220 гр. Відповідно до завдань дослідження експериментальні тварини розподілялися на 2 групи. З них 5 тварин були контролем. В експериментальній групі (n=120) моделювали тривалу гіпокінезію. Для цієї мети тварини були розміщені в спеціальних клітках-пеналах на 240 діб. Для дослідження служили скелетні м'язи, які забирали у лабораторних тварин через 30, 60, 90, 120 і 240 днів від початку моделювання гіпокінезії.

Також був досліджений вплив фізичних навантажень середньої потужності аероба на відновлення м'язових волокон після атрофічно-деструктивних змін після тривалої гіпокінезії. Встановлено, що ступінь атрофії і деструктивних змін у волоконних і судинних компонентах скелетних м'язів знаходиться в прямій залежності від терміну обмеження рухової активності. Застосування кинезіотерапії підсилює репаративні процеси, які істотно скорочують час відновлення структурно-функціональних властивостей скелетних м'язів після тривалої гіпокінезії.

***Ключові слова**: гіпокінезія, м'язові волокна, кровоносні судини, фізичне навантаження.*

В условиях морфологического эксперимента исследовали скелетные мышцы лабораторных крыс в условиях длительной гипоканезии и последующей физической нагрузки средней аэробной мощности.

Опыты производились на 125 крысах с весом тела 120–220 гр. В соответствии с задачами исследования экспериментальные животные распределялись на 2 группы. Из них 5 животных были контролем (КГ). В экспериментальной группе (ЕГ, n=120) моделировали длительную гипокинезию. Для этой цели животные были размещены в специальных клетках-пеналах на 240 суток. Для исследования служили скелетные мышцы, которые взяли у лабораторных животных через 30, 60, 90, 120 и 240 дней от начала моделирования гипокинезии.

Также было исследовано влияние физических нагрузок средней аэробной мощности на восстановление мышычных волокон после атрофично-деструктивных изменений после длительной гипокинезии. Устанавлено, что степень атрофии и деструктивных изменений в волоконных и сосудистых компонентах скелетных мышц находится в прямой зависимости от срока ограничения двигательной активности. Применение кинезиотерапии усиливает репаративные процессы, которые существенно сокращают время обновления структурно-функциональных свойств скелетных мышц после длительной гипокинезии.

***Ключевые слова**: гипокинезия, мышечные волокна, кровеносные сосуды, физическая нагрузка.*

In conditions of experiment morphological research of skeletal muscles and physical loading of middle aerobic power in rats after long time hypokinesia.

The experiments were conducted on 125 rats by weight of body 120–220 g. In accordance with the tasks of research experimental animals were distributed on 2 groups. From them 5 animals were a control (KG). In an experimental group (EG, n=120) designed long time hypokynesia. For this purpose animals were placed in cages-pencil-cases on 240 days. For research the skeletal muscles which took at experimental animals in 30, 60, 90, 120 and 240 days from the beginning of the hypokynesia design were material.

Influence of the physical loadings of middle aerobic power on the regeneration of muscle fibres after the atrofic-destructive changes under influencing of long hypokynesia is explored in experimente. It is set that degree of atrophy and destructive changes in myogenic and vascular components of skeletal muscles is in direct dependence on the term of limitation of motive activity. Application of kinesiotherapy intensifies the reparative regeneration, that substantially abbreviates the terms of renewal of structurally-functional properties of skeletal muscles in the conditions of hypokinesia.

***Keywords:** hypokinesia, muscle fibers, blood vessels, physical load.*

Entry. Dystrophic and the atrophic processes in the skeletal muscles of various genesis rather often arise up on bedrock of previous of long duration hypokinesia, which by life conditions, character of work, age, various diseases, immobilization of various parts of a man

body after the traumas of a locomotorium and so forth [5, 7]. It is known that in conditions of hypokinesia not only metabolism of muscles varies [1, 4, 8, 10], but also their structure changes [6, 8]. Search of factors which strengthen the reparative regeneration and renewal of function of muscular fibers after hypokinesia allowed to set positive influence on these processes of the dosed physical loading [8 ,9]. Taking into account his powerful stimulant influence on various organs and fabrics of human organism [6, 10], we put by a purpose our research to learn character of structural alteration of skeletal muscles, which arises up under act of the dosed physical loading of middle aerobic power after of long duration hypokinesia.

Materials and methods. Researches are conducted on 60 adult not thoroughbred (1 annual) rats-males. Limitation of motive activity on the method [3] offered by us, term of hypokinesia 300 days. The physical loadings were designed in tredmile (daily trainings during 15 minutes at speed at run 20 м/хв during 30 days). Taking away of material during experimental hypokinesia was conducted on 7, 180 and 300 days. After the dosed physical loading animals were destroyed from the experiment in obedience to Rules of humane conduct with laboratory animals (by overdosing of ether anesthesia). Material for histological and electronic microscopic research was prepared on the generally accepted method.

Results of research and their discussion. The results of the conducted researches were witnessed, that in basis of structure of muscle fibers a morpho-functional complex lies to which enter: myofibriles, blood vesels and nerve-muscle ending. Drawing on complex morphological research, it is set by us, that distinguish muscular fabers not only after the row of ultrastructure signs (by an amount and diameter of myofibers, distributing and localization of kernels and mitochondria, size Z-lines, by the amount of glycogen and lipid including) but also on hystochemicaly indexes, that enables to divide them into separate phenotipe muscle fibers. Research of thigh direct to the muscle by hystochemicaly methods allowed to expose three types muscle fibers: fasts of oxygen-glycolitics (FOG), fasts of glycolitics (FG) and slow oxidizing (SO) (fig. 1).

Mitochondria of different phenotipe is selected by considerable heterogenity, both after ultrastructure and localization in a cage and after biochemical properties.

The far of the lipid including and plenty of glycogen in all departments muscle fibers are the electronic-microscopic signs of the muscle fibers SO-type, and also large by volume closeness of mitochondria of a different size (fig. 1 a), which occupy on the average to a 15,68±1,18% volume muscle fibers. Have myofibers well expressed band H with M-line and Z-line size 100,0–110,0 nm. Sarcoplasmic network has enough the thick net of canaliculi and small terminal cisterns are comparative. Kernels which are localized subsarcolemmatic have well differentiated nucleoly.

FOG muscle fibers is characterized less (a relative volume is 5,75±0,64% only) and sizes (0,5–0,6 mcm) of mitochondria, which are localized from two sides from a Z-line (fig. 1 b). In them very rarely there are the lipid including, however marked plenty of glycogen is, especially in between fibrilary spacious at the level of I-discus, under sarcolemma and near-by myonucleus (on the average 412,0 ±42,61 granules on 10 mcm^2).

The sarcoplasmic network elements in FOG muscle fibers lots better are developed, than in SO muscle fibers.

On longitudinal cuts in between fibrilary intervals at the level of border of A- and I-discus sarcomers triads (see fig. 1 b) are determined, in which expressly T-tubes differentiate and densely adjoining to them from two sides terminal cisterns.

Maintenance is the important difference FOG muscle fibers considerably wide myofibers with a narrow Z-line (50,0–55,0 nm). Thus often there are myonucleus longitudinal sygaro similar forms and quite often with two nucleoly.

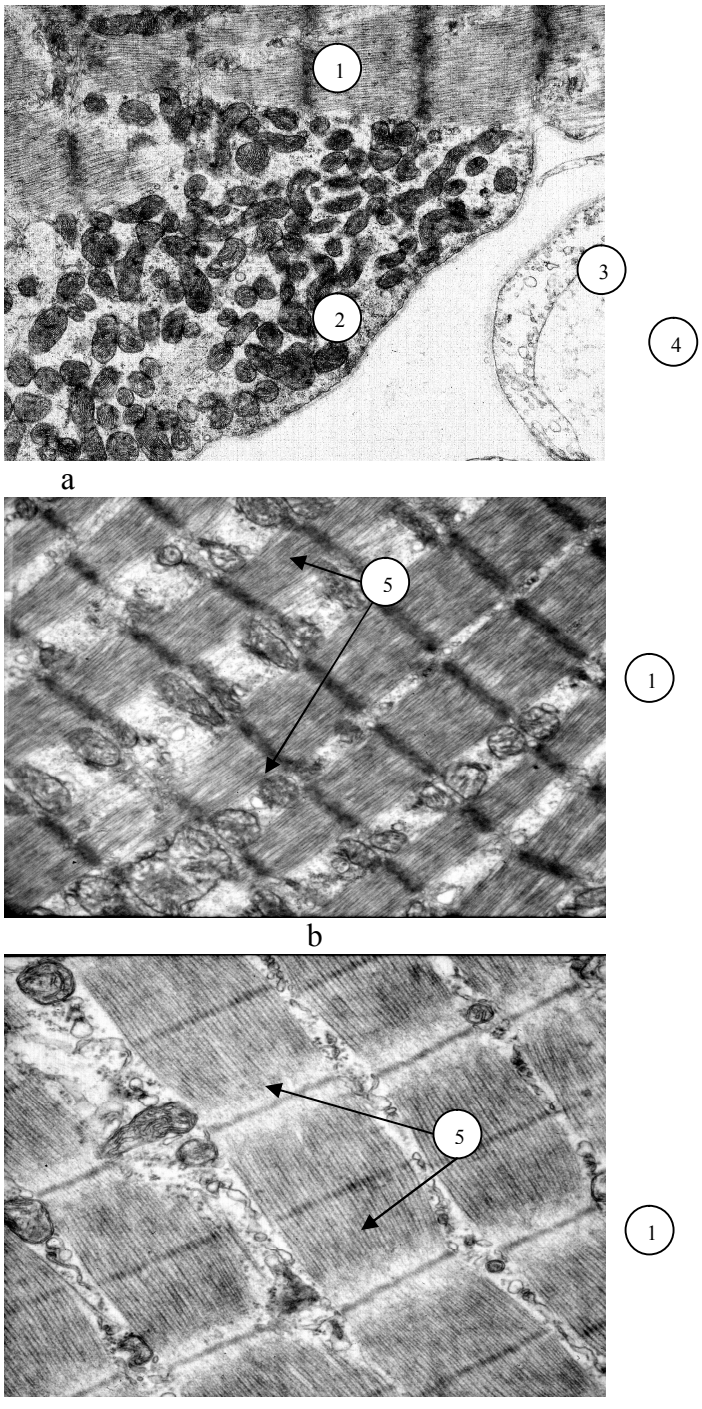

Fig. 1. Ultrastructure organization SO (a), FOG (b) and FG (c) muscle fibers M. rectus femoris of the rats: 1 – myofibers; 2 – mitochondria; 3 – capillary bed; 4 – blood vessels; 5 – narrow shows triads (b) and canaliculi sarcoplasmic network (c).
Magn.: a – x 9500; b – x 10000; c – x 12000

FG muscle fibers differ by a few of mitochondria (fig. 1 c), at the relative volume 4,96±0,18% ($p<0,05$). Sarcoplasmic network elements is developed poorly, his relative volume is 7,26±0,33%. Have FG muscle fibers the widest Z-line (150,0–180,0 nm).

Already on 7 days after development of hypokinesia in endo- and perimysiums there are the phenomena of intensive edema, expressed prolipheration cellular reaction in fabrics which surround vascular-nervous bunches. It is accompanied by the increase at a 1,5 one by volume

fate of stromal components (fig. 2). Has sarcoplasm most muscular fibers low electron-optical density, contains the promoted amount of vacuoles, the transversal striped is lost, kernels are localized near-by central part of fiber. Such phenomenon is unspecific and meets at some myopathies [2], and also as compensative adaptive reaction of muscular fiber to metabolism in anaerobic terms [10].

It is known that an ischemic compression syndrome [7, 9] develops in the conditions of hypokinesia, narrowing of road clearance of bloodvessels, delay of products of exchange and delivery of oxygen passes as a result, that conduces to tissue hypoxia.

Tissue hypoxia, in the turn, is the reason of local hydratation cellular and noncellular components. It is set at the analysis of electronic photomicrographs, that in 180 days of hypokinesia the phenomena of intracellular edema, which conduce to delamination of miofiber, grow in muscular fibers.

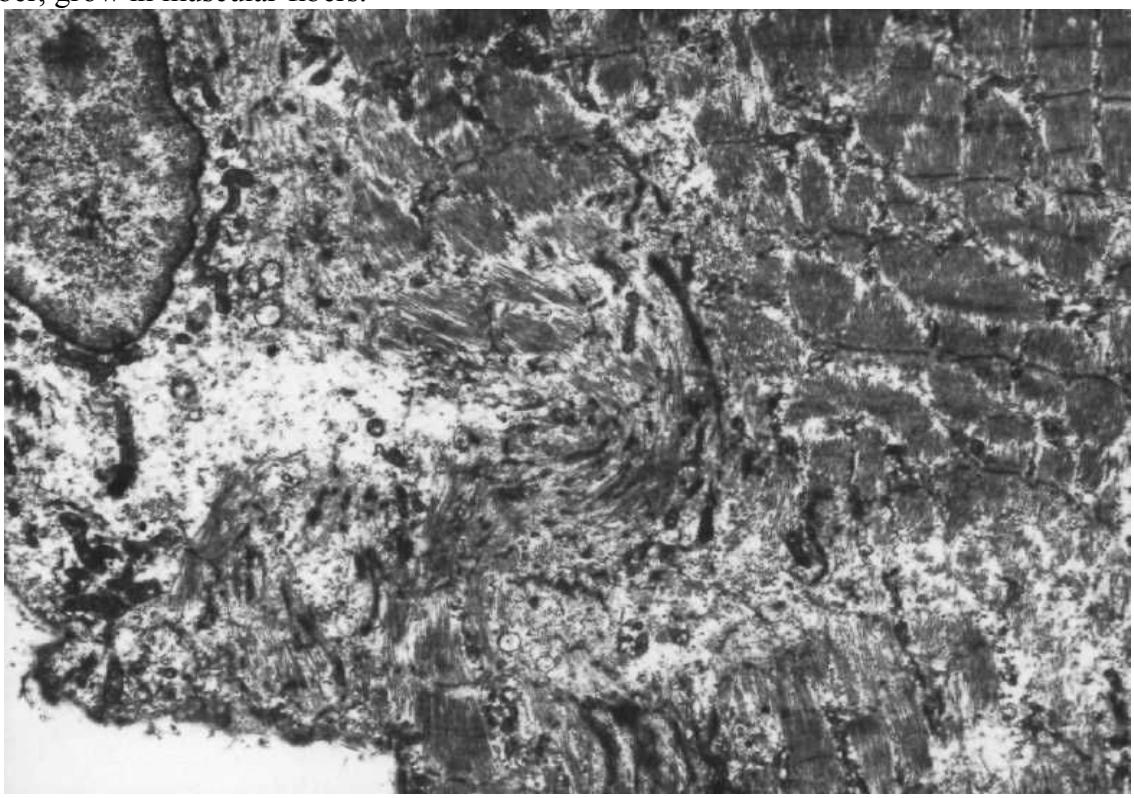

Fig. 2. Destruction near-by nuclear sarcoplasmatics raethyculum of as and result of lysis of myofibrilar vehicle in and FOG-fiber to the muscle soleus after on 7 day's of hypokinesia. Magn.: x 5000.

Formation of mielinlooking parts and vacuolization of a sarcoplasm is the typical phenomenon. It is multiplied mitochondrions in sizes, their matrix has a low electronoptic density, crests disoriented, shortened, fragmented (fig. 3).

The such structural changes are the reason of diminishment of active working surface of mitochondrions and create pre-conditions for the origin of the ATF deficit. The cisterns of sarcoplasmic net and the Goldgy complex are extended, that testifies to activating of synthetic processes on membranes these organels. Lizosomes is concentrated mainly in the areas of destruction of miophibrils. There is the promoted amount of including of various electro-noptical of density in sarcoplasmic (fig. 4).

There is diminishment of edema and increase of specific fate of stromal component of muscles in 300 days of hypokinesia.

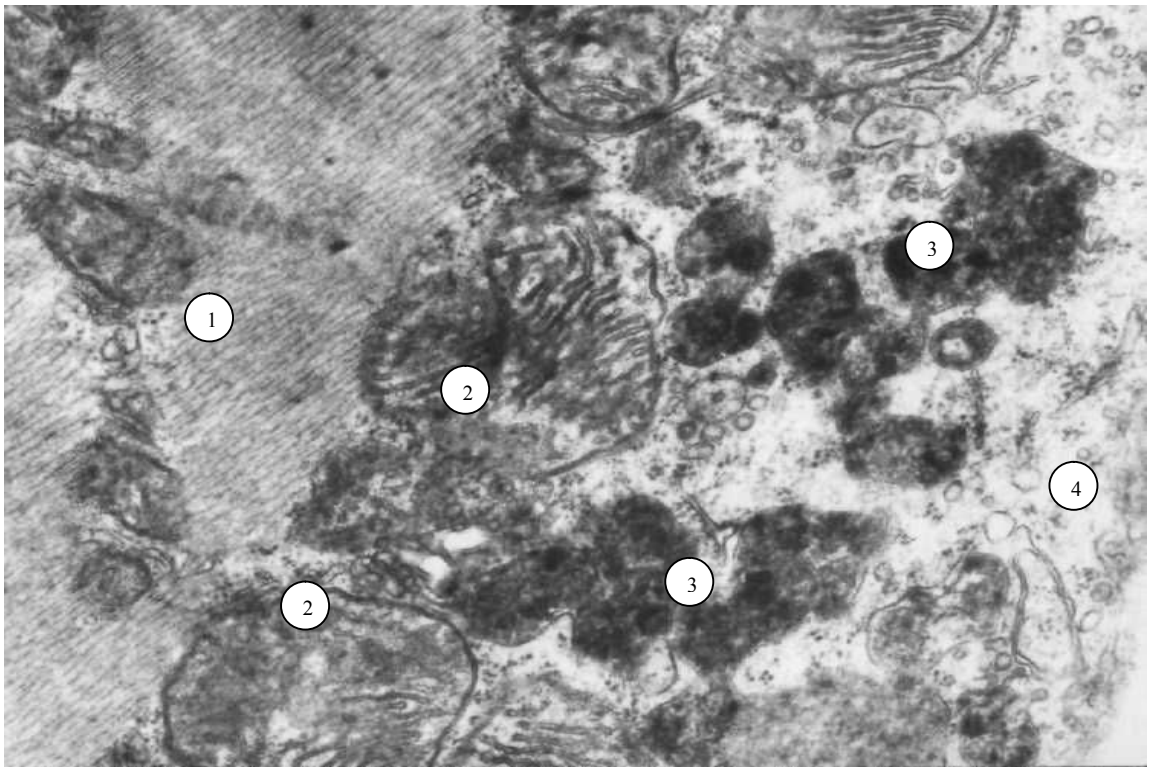

Fig. 3. Formations of lamelar little bodies and lipid to including at the sarcoplasma FG- muscular fiber of muscle soleus after 180 day's hypokynesia: 1 – myofibriles; 2 – mitochondria, 3 – little T-body; 4 – myoplasma.
Magn.: x 12000

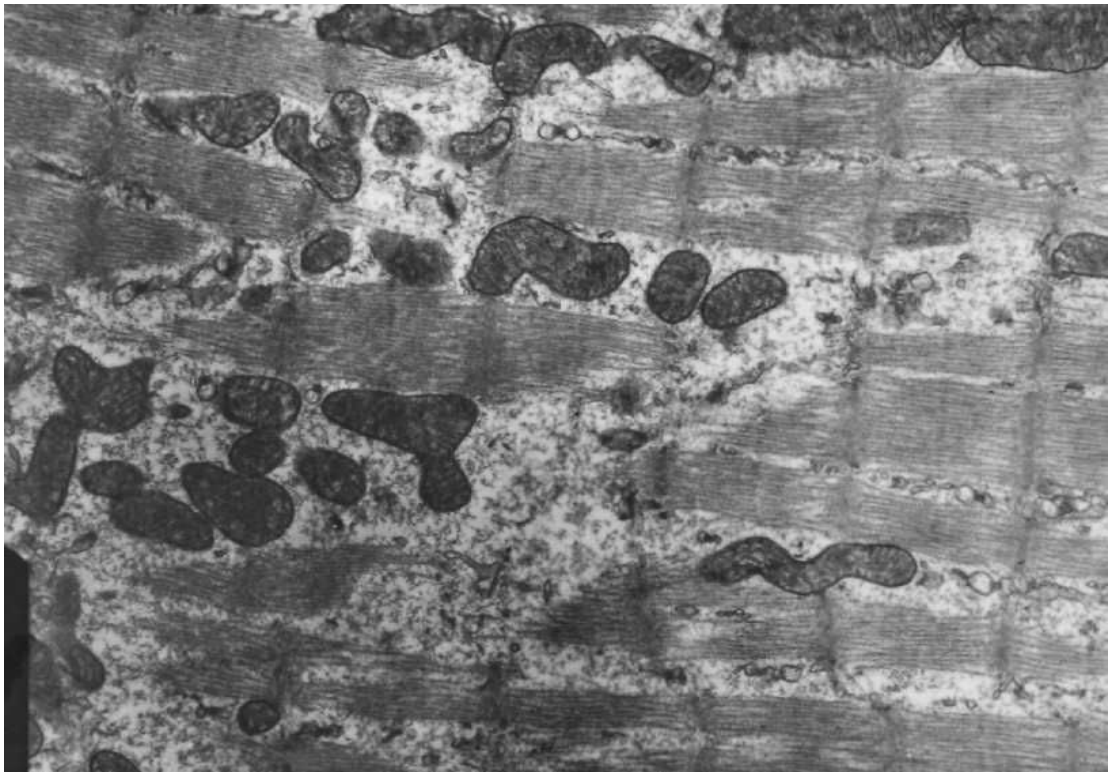

Fig. 4. Multiplied mitochondrions in sizes, their matrix has a low electronoptic density, crests disoriented, shortened, fragmented of muscle soleus after 180 day's hypokynesia.
Magn.: x 12000

Thus the promoted amount of macrophages, lipoblasts and fibroblasts with the proper increase of number of collagenic and silverness fibers which lie on as large bunches parallel longitudinal axis of blood vessels appears in connective tissue framework of muscles. For most muscular fibers the characteristic dystrophic-atrophy and necrotic phenomena.

Muscular fibers are refined, is lost transversal striped, the local bulges are sometimes formed. It is thus needed to mark that intensity of defeat in a greater measure is shown in oxidizing-glicolitic fibers. This phenomenon it is possible to explain by diminishment of expressed of compression syndrome, that is instrumental in expansion of blood vessels and strengthening of their drainage function. As a result of this pH environment changes in an alkaline side. It is known that oxidizing-glicolitic fibers collapse more intensive in an alkaline environment [7, 9]. At electronic-microscopic research in this period of experiment in the muscular fibers of hearth the defeats carry diffuse character. Muscular fibers diminish in a diameter, quite often there are the phenomena of their lysis. In such areas is multiplied the amount of autofogosoms and remaining little bodies. The kernels of muscular fibers have uneven contours, clarified nucleoplasm and border chromatin. Mitochondrions with clarified matrix, fragmented and sharply reduse crests, sometimes there is destruction of external membrane, that conduces to diminishment of the SDG activity in rapid oxidizing-glicolitic fibers (fig. 5).

The physical loading after 300 day's hypokinesia gives the expressed and rapid recreational effect. In short space (15 days) the initial amount of locuses destruction of muscular fabric goes down considerably. The degree of expressed of this destruction changes also: necrotic areas do not meet practically, there are the only refined, winded, without transversal and longitudinal striped of fiber. As compared to the results of I-series researches the phenomena of edema are shown in a less measure. There is the insignificant increase of amount of connecting tissue elements. However, foregoing processes take place on the limited areas of transversal to the cut of muscular fabric, does not have a tendency to generalization and will be liquidated in the first 10–15 days after the physical loading of middle intensity.

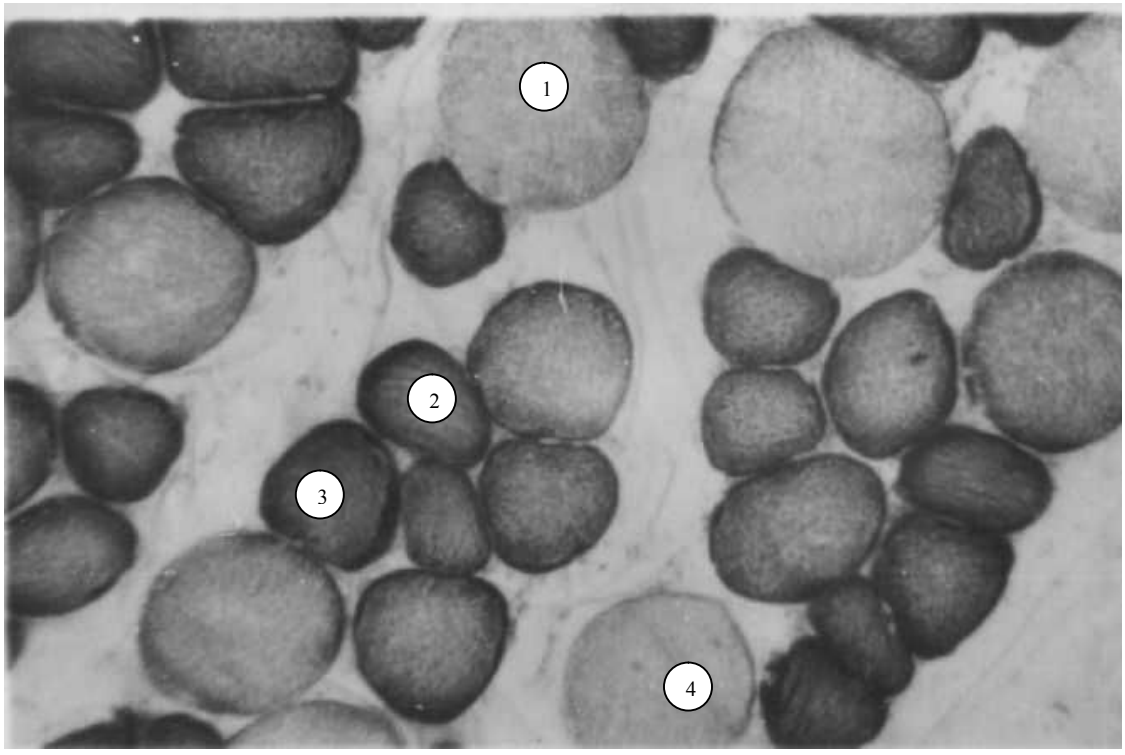

Fig. 5. Activity of ferments reaction on SDG in the muscular fibers of different types through 300 day's hypokynesia. Serial transversal cuts of muscle soleus: 1 – FOG muscular fiber; 2 – FG muscular fiber; 3 – SO muscular fiber; 4 – defermentive muscular fiber. Magn.: x 600

At the increase of multiple of action of the physical loading (16–30 days) the far of the fatty including appears in sarcoplasm, the channels of sarcoplazmatic net are extended. Pays on itself attention of increase of absolute number of capillaries, which is on an area 1 мм^2 transversal to the cut to the muscle (fig. 6). At the same time, beginning from the end of the first week, is multiplied the area of the mutual ceiling of areas of blood suplly between next gemovessels. Microrelief of luminative surface is smoothed out in endotheliocytes, an amount and diameter of micropinotic of vacuoles rises.

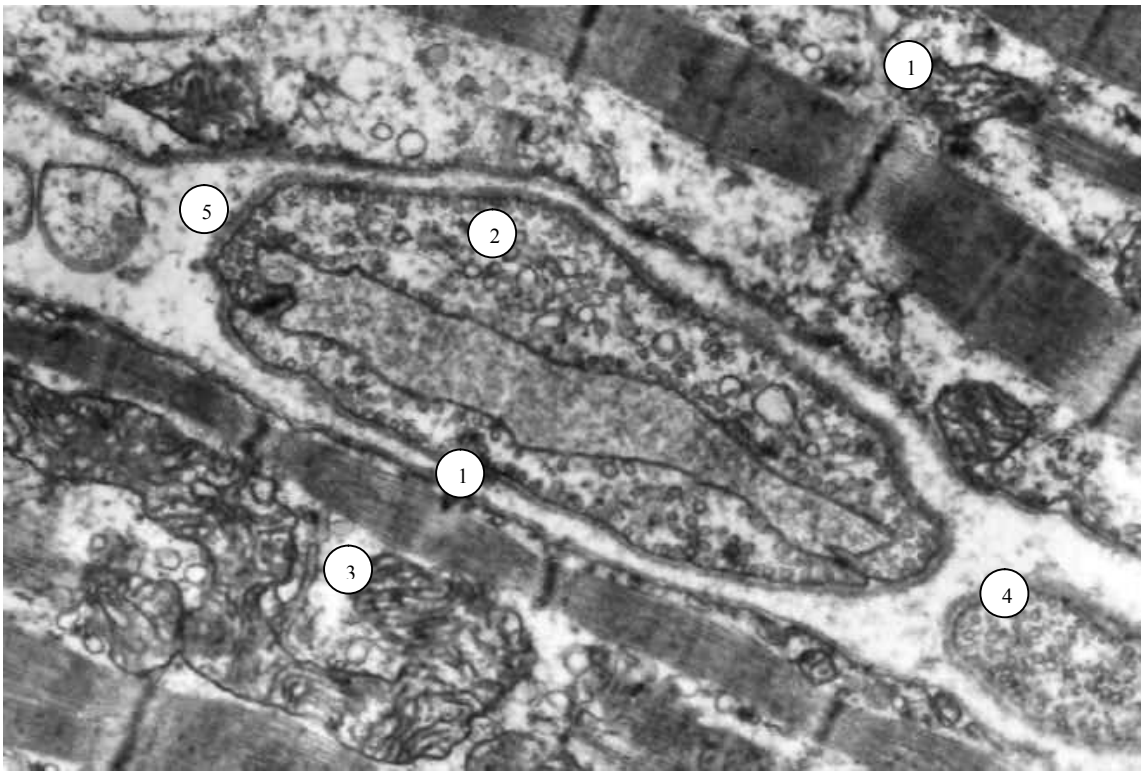

Fig. 6. Edema of cytoplasm of endotheliocytes of the hemocapillar muscle soleus to the muscle on 20 time of period of rehabilitation at the increase of multiple of the physical loading of middle aerobic power: 1 – muscular fiber; 2 – cytoplasm of endotheliocytes cages; 3 – mitochondria, 4 – neuro-muscular endings, 5 – sprouts of fibroblasts.
Magn.: x 8000

All of it represents close character of mutual alteration of blood vessels net work and component components of muscles under act of the promoted motive activity.

Consequently, speed-up renewal of muscular fabric under act of the physical loading testifies to stimulation of metabolic processes which will be realized through strengthening of function of intracelullar organels, which provide a muscular fiber by energy and plastic material.

More powerful regenerative effect which is observed at complex action of the physical loading of middle aerobic power it is possible to explain by influencing of active mechanical stretch of the dystrophic changed muscular fibers, on a background the activated circulation of blood in muscles during at run, that supports at them metabolic processes at more high level, than only at exceptional application of pharmacological preparations.

The thus dosed physical loading of aerobic character strengthens the reparative regeneration of muscular fibers after of long duration hypokinesia.

1. Gausmanova-Petrusevich, I., (2011), Myshechnye zabolevanija [Muscle diseases]. Varshava, 1971, 320 s.
2. Kovalenko, E. A., Gyrovskij N.N., (1980), Gipokinezija [Hypokinesia]. M., Medicina, 318 s.

3. Mickan, B. M., (1997), Vpliv gipokineziї i ruhovoї aktivnosti na rist i diferenciaciju skeletnih m'jaziv [Influence of Hypokinesia and motive activity on growth and differentiation of skeletal muscles]. Avtoref. dis. … dokt. biol.. nauk. Kiïv, 42 s.
4. Podrushnjak, E. A., (2009), Myshechnaja sistema cheloveka pri starenii [Muscle system of man at the senescence]. K, Zdorov'e, 115 s.
5. Solov'jov, V. A., (2014), Harakteristika zhevatel'nyh myshc cheloveka v uslovijah gipokinezii [Description of masticatory muscles of man in the conditions of hypokinesia]. Morphol 102(9), 77–83.
6. Studitskij, A. N., (1988), Istoricheskij metod v issledovanii funkcional'no# morfologii myshechnoj tkani [Historical method in research of function morphology of muscle fabers]. Vozrastnye, adaptivnye i patologicheskie processy v oporno-dvigatel'nom apparate. Har'kov, 39–41.
7. Srihari, T., Seedorf, V., Pette, D., (2010), Ipsi- and contralateral changes in rabbit soleus myosins by cross-reinnervation. Pflugers Arch. 390(3), 246–249.
8. Hopkins, D.A., Manchester, K.,L., (2011), The influence of section on the metabolism of poliamines in rat diaphradm muscle. Biochem. J. 196(2), 60–610.
9. Jeffrey, P.,L., Leung, W.N., Postas, J. A. P., (2009), Denervation alteration in surface and brain degeneration. Proc. Symp., Sydney-Amsterdam, Oxford: Publish. House Oxford Univ, 32–43.
10. Joles, F., Sreter, F.A., (2008), Development, innervation and activity pattern induced changes in skeletal muscle. Annu. Rev. Physiol. 43, 531–552.

Рецензент: канд. біол. наук, доц. Лісовський Б.П.

УДК 796.853.23: 796.012.1–053.67
ББК 75.0

Олександр Верітов

ЕФЕКТИВНІСТЬ ВИКОРИСТАННЯ ЗАСОБІВ КАРДІОТРЕНУВАННЯ НА РІВЕНЬ ФІЗИЧНОЇ ПРАЦЕЗДАТНОСТІ ТА ФУНКЦІОНАЛЬНОЇ ПІДГОТОВЛЕНОСТІ ДЗЮДОЇСТІВ 7–17 РОКІВ

Рівень фізичної та функціональної підготовленості спортсменів у дзюдо в значній мірі залежить від поточного стану серцево-судинної і дихальної систем організму. У зв'язку з цим, досить перспективним напрямком удосконалення підготовленості дзюдоїстів на різних етапах багаторічної спортивної підготовки може бути впровадження в тренувальний процес засобів кардіотренування, основним змістом якої є використання фізичних вправ аеробної спрямованості. Розробка, експериментальна апробація та практичне впровадження в тренувальний процес дзюдоїстів 7–17 років програми тренувальних занять, що включає засоби кардіотренування, яке сприяє підвищенню рівня їх фізичної та функціональної підготовленості, ефективності тренувального процесу визначило актуальність дослідження.

Ключові слова: *дзюдо, кардіотренування, фізична працездатність, функціональна підготовленість.*

Уровень физической и функциональной подготовленности спортсменов в дзюдо в значительной степени зависит от текущего состояния сердечно-сосудистой и дыхательной систем организма. В связи с этим, достаточно перспективным направлением совершенствования подготовленности дзюдоистов на различных этапах многолетней спортивной подготовки может быть внедрение в тренировочный процесс средств кардиотренировки, основным содержанием которой является использование физических упражнений аэробной направленности. Разработка, экспериментальная апробация и практическое внедрение в тренировочный процесс дзюдоистов 7–17 лет программы тренировочных занятий, включающей средства кардиотренировки, способствующей повышению уровня их физической и функциональной подготовленности, эффективности тренировочного процесса определило актуальность исследования.

Ключевые слова: *дзюдо, кардиотренировка, физическая работоспособность, функциональная подготовленость.*

The physical and functional training judokas is largely dependent on the current state of the cardiovascular and respiratory systems. In this regard, quite promising way to improve the readiness of wrestlers at various stages of long-term sports training may be the implementation of a training process means cardio, the main content of which is the use of aerobic exercise orientation. Development, experimental testing and practical implementation in the training process judokas 7–17 years old program of training sessions, including