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Functional state of autonomic nervous system, central hemodynamics, and physical work capacity in former track and field athletes

***Prof. Dr. Evgeny Mikhalyuk*[1], *Prof. Dr. Larisa Gunina*[2]**
Zaporozhye State Medical University, Ukraine[1]
National University of Physical Education and Sport of Ukraine, Ukraine[2]

Summary

The article presents comparative data of complex functional state examining of 24 highly skilled female athletes who were engaged in 100 to 400 m running at a young age. 12 females (group I) have been continuing active physical exercise training after withdrawal from competitive sport. Comparison group (group II) included 12 females who have been conducting a sedentary lifestyle after withdrawal from competitive running. The two main groups were compared considering the level of sport skills. 12 females never engaged in any sports training with insufficient level of motor activity formed the control group.

Mathematical methods for analysis of cardiac rhythm variability were used to analyse cardiac activity vegetative regulation. Major parameters of central hemodynamics were studied by the method of automated tetrapolar rheography, followed by determination of stroke volume, cardiac output, stroke volume index, cardiac index, and peripheral resistance.

PWC_{170} submaximal cycle ergometer test was applied to determine physical work capacity. Functional state was estimated on the basis of the index, calculated according to our suggested and registered formula. In the former athletes continuing physical exercise training as compared to those conducting a sedentary life style some increase of autonomic nervous system parasympathetic influences, a tendency to hypokinetic circulation type prevalence, a greater number of persons with "above average" and "below average" estimates of functional state index, and lack of differences in body mass index between the period of sports training and that of today were revealed. In former athlete conducting a sedentary lifestyle an increased influence of autonomic nervous system sympathetic link and prevalence of eukinetic circulation type were noted. Besides, 91.7% of former athletes had "low" estimate of functional state and significantly higher body mass index as compared to the latter during the period of active sports practice. Significant prevalence of autonomic nervous system sympathetic link, less common hypokinetic circulation type ($p = 0.007$), lower level of physical work capacity and functional state index were observed in the subjects of the control group, never engaged in sports activity, as compared to physically active former athletes. No differences were observed between the control group subjects and those of the group II in all studied indices. A tendency to body mass index increase by 3.9% ($p > 0.05$) was noted in former athletes of the group I 21.36 ± 3.6 years after withdrawal from competitive sport as compared to significant increase of the above index by 13.9% and 27.1% in former athletes of the group II and control group subjects, respectively.

Functional state of former athletes proceeding with physical exercise training after withdrawal was higher as compared to now sedentary lifestyle following former athletes and those never engaged in any type of sports activity, thus, indicating an expediency of continuing strictly individual physical exercise training after withdrawal from competitive sport.

Keywords: *former athletes, track and field, heart rate variability, central hemodynamics, autonomic nervous system, physical work capacity.*

Introduction

A prominent Greek physician Claudius Galen, better known as Galen of Pergamon (AD 131-200), noted that "<...> the life of an athlete is quite the opposite to what hygiene prescribes, and I believe that their life style contributes to diseases rather than health... During training, the body of athletes is subjected to danger, and after withdrawal they fall in a state, when some of them die fairly soon, while others live for a while, but never reach the sunset years". The majority of modern researchers refutes the above statements of outstanding

physician of antiquity. While noting a positive correlation between physical exercises, on the one hand, and prevention of heart disease and overall life expectancy, on the other (Шархаг et al., 2013; Gajewski, 2008; Kettunen Jurki et al., 2015), the authors of numerous publications indicate decreased mortality rate due to myocardial infarction in former athletes as compared to general population (Kroger et al., 2011). Moreover, proper training regimen along with healthy way of life may allow living up to 81-96 years and enjoying active lifestyle as is the case of professional cyclists (Ердаков, 2007). Physical activity tends to delay the development of such diseases as non-insulin dependent diabetes (Galassetti, Riddell, 2013; Shin et al., 2012), obesity (Bermudez, Pories, 2013), atherosclerosis, and coronary artery disease (CAD) (Горчакова et al., 2010). Previous sport activities positively influence cardiovascular system compensatory abilities during development of atherosclerosis and CAD in athletes as well as improve the course and prognosis of CAD treatment. It may be due to larger lumens of coronary arteries as a result of previous regular physical loads and, thus, less arterial occlusion and more beneficial impact of pharmacological therapy upon myocardium and coronary artery elasticity (Михалюк, 1987; Chevalier et al., 2017).

Athletic longevity as an important social and cultural phenomenon has recently become one of the most popular objects of scientific studies. One can hardly find more convincing arguments in favour of healthy way of life, which is best illustrated by athletic and professional achievements of former athletes (Камалова, 2009).

While speaking about the regularities of adaptation processes in persons engaged in sports activity, one may interpret the changes occurring in the body of athlete during abrupt termination of training activity in terms of stress doctrine. Not only the athletic training and its induced physical and emotional impacts may be a stressor. Abrupt withdrawal from the training process may also represent itself as strong irritator. Sports training termination necessitates the adjustment to a new environment with unusual motor regimen, unfamiliar mental and social factors, etc. (Гильмутдинов, Епишев, 2009).

Sports career termination is one of the critical periods in the life of athletes, frequently leading to development of different pre-pathological and pathological states (Федотова, 2009). Peculiar age changes and disorders of cardiovascular system at higher functional capacities of circulation are less frequently revealed or manifested to a lesser degree in former athletes continuing physical exercise training (Талибов, 2011).

Our studies have also demonstrated (Михалюк, 1987, 1989, 2015) the reasonableness of comparing former athletes to their non-athletic peers in order to study either positive or negative impacts of specific sports event loads upon human body. Besides, a comparison may be made between former athletes of the same sex and sports event continuing physical exercise training and those conducting a sedentary lifestyle.

The object of the work is to study and compare the parameters of autonomic nervous system, central hemodynamics, and physical work capacity of former athletes continuing physical exercise training after withdrawal from competitive sport, those conducting a sedentary lifestyle, and control group subjects never engaged in any kind of sport activities.

Material and methods

24 former female athletes were studied for this research: 12 former 100 to 400 m runners who have continued active physical exercise training (aerobics, shaping, swimming, etc.) 2–3 times per week (30-45 min) either in recreational groups or individually constituted the group I (mean age 45.3 ± 4.2 years). The group II of 12 former female athletes (mean age 46.0 ± 4.6 years) conducting a sedentary lifestyle after sports career termination was formed to compare the impact of current way of life after withdrawal from competitive running. The control group was composed of 12 females (mean age 48.5 ± 2.9 years) never engaged in any kind of sport or motor activity. As seen from presented data, all compared groups did not differ significantly in age criterion.

Among the former athletes, there were 3 International Class Masters (ICM), 9 Masters of Sport of the USSR (MS), 6 Candidates in Masters of Sport (CMS) and 6 athletes of the category I. They participated in the Olympic Games and were medal winners of the World Universiade, champions and prize winners of European Championships and Cups, USSR and Ukrainian Championships. Group I included 2 ICM, 4 MS, 3 CMS and 3 athletes

of the category I, whereas the group II – 1 ICM, 5 MS, 3 CMC and 3 athletes of the category I. Thus, the level of sports skills of both groups of former athletes did not differ statistically.

"CardioPlus" (Ukraine) automated diagnostic complex providing automatic analysis of cardiac rhythm variability and central hemodynamics was used for the research. Vegetative regulation of cardiac activity was analysed by mathematical methods for cardiac rhythm variability analysis (Баевский, 2002). Cardiac rhythm parameters, suggested by working group of The European Cardiology Society and The North American Society of Pacing and Electrophysiology, were used in the study (Heart Rate Variability, 1996). Recording and subsequent processing RR intervals permitted to determine several statistical characteristics of cardiac rhythm variability: mode (Mo, s), its amplitude (AMo, %), and variation range (D, s). In addition, several secondary indices were calculated: vegetative balance index (AMo/D, %/s), rhythm vegetative index (RVI, $1/s^2$), index of activity of regulation processes (IARP, %/s), index of tension (IT, c.u.). Analysis and evaluation of cardiac rhythm periodic components were performed by examining spectral indices of autocorrelation functions: LF (ms^2) as an indicator of predominantly sympathetic tone, HF (ms^2) reflecting parasympathetic activity, and total spectrum power TR (ms^2). The power in the range of low (LFn, %) and high frequencies (HFn, %) and the ratio of the mean values of low- and high-frequency component of cardiac rhythm (LF/HF, c.u.) were calculated as well (Баевский, 2002).

Modified method of automated tetrapolar rheography, according to W. Kubiček et al. (1970), was used to study central hemodynamics (Пушкарь et al., 1977; Kibiša et al., 2013). Stroke volume, minute volume, stroke volume index, cardiac index, and total and specific peripheral resistance were determined. According to classification (Jae et al., 2017), athletes with values in the range of 2.750–3.500 $L \cdot min^{-1} \cdot m^{-2}$ were referred to eukinetic type of circulation (TC), those with values below 2.750 $L \cdot min^{-1} \cdot m^{-2}$ – to hypokinetic TC, whereas those with cardiac output value above 3.500 $L \cdot min^{-1} \cdot m^{-2}$ – to hyperkinetic TC. Physical work capacity was determined on the basis of PWC170 submaximal cycle ergometer test (Баевский, 2002) and calculation of relative value of physical work capacity per kg of body mass (PWC_{170rel}). Index of functional state (IFS) was calculated according to our suggested and registered formula (Михалюк, 2008).

The findings were processed by the method of variation statistics with utilization of Statistica 6.0 application software package for Windows. The values of the arithmetic mean (M) and the errors of the arithmetic mean (m) were calculated in all groups. The studied quantitative traits with normal distribution are presented as M±m. The significance of differences between the groups was assessed according to the Student's test, the differences were considered significant at $p<0.05$ (Боровиков, 2001). Pearson correlation coefficients were used for correlation analysis.

Results and discussion

Significant differences between the groups of former athletes were not observed: 12.8 ± 1.4 vs. 11.3 ± 1.0 years, respectively, height – 166.8 ± 0.8 vs. 167.8 ± 2.0 cm and body mass 59.8 ± 1.9 vs. 66.4 ± 2.6 kg.

Comparison of cardiac rhythm variability characteristics demonstrated the lack of significant differences between the groups I and II with respect to frequency indices. Concerning temporal indices, only the index D, indicating maximum amplitude of cardiac rhythm fluctuations and depending on the impact of vagus nerve, was 79,3% higher than that in former athletes of the group II 0.52 ± 0.1 vs. 0.29 ± 0.0 s ($p < 0.05$), which may be indicative of the prevalence of autonomic nervous system parasympathetic link. Individual analysis of the values of tension index speaks in favour of parasympathetic influence prevalence as well. For instance, among the subjects of the group I there were 3 persons with vagotonia (TI < 30 c.u.), 6 with eutonia (TI = 30–90 c.u.), and 3 with sympathicotonia (TI = 90–300 c.u.) (Лунина et al., 2007), whereas in the group II this ratio was as follows: 0, 4, 8 subjects.

Values of central hemodynamics in compared groups were consistent and did not differ significantly. Average value of cardiac output in the group I constituted 2.644 ± 0.1 $L \cdot min^{-1} \cdot m^{-2}$, which corresponded to hypokinetic type of circulation, whereas in the group II it was equal to 2.925 ± 0.2 $L \cdot min^{-1} \cdot m^{-2}$, which corresponded to eukinetic type of circulation. Obtained data were confirmed by percentage ratio of circulation types, which constituted 58.3 : 41.7 : 0 (hypo-, eu- and hyperkinetic types, respectively) and

33.3 : 58.4 : 8.3 (p = 0.098) in former athletes of the groups I and II, respectively. Therefore, in former athletes of the group I the tendency to hypokinetic type prevalence was observed. Besides, there were no athletes with hyperkinetic type of circulation in this group.

Average values of PWC_{170rel}, which constituted 13,51 ± 1,0 $L \cdot min^{-1} \cdot kg^{-1}$ and were 8,1% higher in subjects of the group I as compared to those of the subjects from the group II tended to decrease. The value of functional state index in the group I constituted 5.163 ± 0.6 rel.un. and was 17,4% higher than that in the group II (4.267 ± 0.3 rel. un.); however, statistical analysis demonstrated the lack of significant differences. It is noteworthy that functional state index in both groups corresponded to "low" estimate. Individual analysis of functional state index characteristics demonstrated that the group I included one female with "above average" estimate, 3 – with "below average" and 8 – with "low" estimates. In the group II there were one subject with "below average" estimate and 11 – with "low" estimates. Thus, the objective characteristics of functional state of the group I subjects were higher as compared to those of the group II.

The value of systolic blood pressure in former athletes of both groups was within normal range on the average. In five subjects from the group I and six subjects from the group II it was in the range of 130–170 mm Hg and 130–140 mm Hg, respectively. At the same time, in the control group subjects, never engaged in any type of sports activities, significantly higher values were observed indicating an obvious tendency to systolic arterial pressure changes depending on previous level of physical loads.

Our findings demonstrate that peculiarities of hemodynamics, occurring as a consequence of training process of track and field throwers, are preserved, although, to a lesser extent both in former athletes continuing physical exercise training and those conducting a sedentary lifestyle. However, in the latter they are expressed to a lesser degree. Therefore, preserved peculiarities of hemodynamics may be considered as a factor reducing the risk of hypertension (Михалюк, 1987).

Analysis of the body mass has shown that in former athletes of the group I body mass index (BMI) during the period of active sports training constituted 20.5 ± 0.4 on the average and remained practically unchanged by the time of studies. In subjects of the group II the BMI constituted 20.8 ± 0.5 and 23.7 ± 1.0 $kg \cdot m^{-2}$ ($p < 0.01$) during the period of sports engagement and by the time of studies, respectively, i.e. it has significantly increased by 13.0%. As it concerns the dynamics of the BMI in the control group, the following values were observed: 20.7 ± 0.3 $kg \cdot m^{-2}$ (age range corresponding to the period of active sports training of the subjects of the groups I and II, i.e., 18–30 years) and 26.31 ± 1.7 $kg \cdot m^{-2}$ (time of conducting studies) ($p < 0.001$), i.e., it has significantly increased by 27%.

Comparison of indices of the subjects from group I and control group has not revealed significant differences in age 45.3 ± 4.2 vs. 48.5 ± 2.9 years, height – 166.8 ± 0.8 vs. 166.0 ± 2.2 cm and body mass – 59.8 ± 1.9 vs. 65.7 ± 3.1 kg, respectively ($p > 0.05$ in all cases).

Temporal indices of cardiac rhythm variability were indicative of significantly lower values of AMo index, reflecting the degree of centralization of cardiac rhythm control, and constituted 39.57 ± 4.5 and 57.41 ± 4.5% ($p < 0.05$), respectively, and the value of regulation process activity index, reflecting the correlation between the activity of sympathetic division of autonomic nervous system and the main level of sinoatrial node functioning, – 48.7 ± 6.3 vs. 73.0 ± 6.7% ($p < 0.05$), respectively. Lower mean value of index D, suggesting relative prevalence of sympathetic system impacts, revealed in control group subjects as 0.29 ± 0.1 vs. 0.52 ± 0.1 sec ($p < 0.05$), respectively, supplements the concept of autonomic nervous system parasympathetic impact prevalence in subjects of the group I as compared to those of the control group. In addition, the prevalence of parasympathetic influences is further confirmed by individual analysis of the values of tension index, which in subjects of the group I was represented by three former athletes with vagotonia, six – with eutonia and three – with sympathicotonia, whereas in the control group this ratio constituted in subjects1, 2, and 9. Significant differences between compared groups in other temporal and frequency indices of cardiac rhythm variability were absent.

Mean value of cardiac index being the main hemodynamic indicator was equal to 2.644 ± 0.1 $L \cdot min^{-1} \cdot m^{-2}$ and 2.898 ± 0.1 $L \cdot min^{-1} \cdot m^{-2}$ in subjects of the group I and control group, respectively. It is noteworthy that in the group I this value

corresponded to hypokinetic type of circulation, whereas in the control group – to eukinetic type. Percentage ratio of circulation types (hypo-, eu-, and hyperkinetic) in subjects of the group I constituted 58.3 : 41.7 : 0, whereas in those of the control group – 16.7 : 75.0 : 8.3 ($p = 0,007$), which confirmed our conclusions about the prevalence of hypokinetic type in subjects of the group I and the absence of persons with hyperkinetic type in this group as well as the tendency to eukinetic circulation type prevalence in the control group (Fig. 1).

Comparison of physical work capacity values PWC_{170} has shown that its relative value in subjects of the group I was by 27,7% higher than that in the control group and constituted 13.51 ± 1.0 kgm·min^{-1}·kg^{-1} vs. 10.58 ± 0.5 kgm·min^{-1}·kg^{-1} ($p < 0.05$), respectively. Functional state index in subjects of the group I was 39,4% higher than that in the control group, where absolute values corresponded to 5.163 ± 0.6 con.un. vs. 3.703 ± 0.3 con.un. ($p < 0.05$) and obtained values corresponded to "low" estimate. Individual analysis of functional state index has revealed one subject with "above average" estimate, 3 subjects with "below average" and eight – with "low" estimates in the group I, whereas all subjects of the control group had "low" estimates of the given index.

Comparison of indices between the group II and control group failed to demonstrate significant differences in age 46.0 ± 4.6 vs. 48.5 ± 2.9 years ($p > 0.05$), height 167.8 ± 2.0 vs. 166.0 ± 2.2 cm ($p > 0.05$), and body mass 66.4 ± 2.6 vs. 65.7 ± 3.1 kg ($p > 0.05$), respectively.

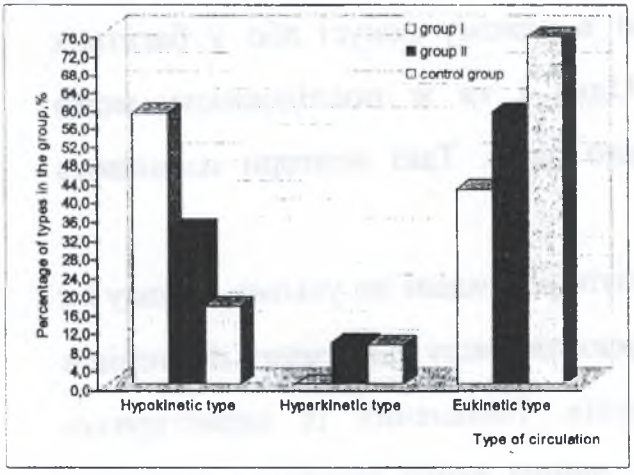

Fig. 1. Ratio of circulatory types in representatives of major groups in comparison with the control group

Temporal and frequency indices of cardiac rhythm variability appeared to be quite similar in both groups. Index of tension in the group II and the control group constituted 132.72 ± 20.0 and 205.75 ± 52.1 c.u. ($p > 0.05$), respectively, indirectly suggesting some prevalence of autonomic nervous system sympathetic impacts in both groups. It was confirmed by individual analysis of tension index values: group II numbered 4 subjects with eutonia, 8 – with sympathicotonia, and no one – with vagotonia, whereas in control group this ratio was 1, 2, and 9.

Mean value of cardiac index in both groups corresponded to eukinetic circulation type and constituted 2.925 ± 0.2 L·min^{-1}·m^{-2} and 2.898 ± 0.1 L·min^{-1}·m^{-2} ($p > 0.05$), respectively. Percentage ratio in the group II and the control group was 33.3 : 58.4 : 8.3 and 16.7 : 75.0 : 8.3 ($p = 0,1$), respectively – corresponded to hypo-, eu-, and hyperkinetic types of circulation (Fig. 1). Obtained ratios confirmed the mean values, indicating eukinetic circulation type prevalence in both groups. Two-sided comparison, however, has shown tendency to the given circulation type prevalence in the control group as compared to the group II ($p = 0,5$). The value of relative physical work capacity in subjects of the group II constituted 12.41 ± 0.7 kgm·min^{-1}·kg^{-1} and was 17.3% higher than that in representatives of control group; however, this difference was insignificant. Functional state index in the group II was 15.2% higher and constituted 4.267 ± 0.3 vs. 3.703 ± 0.3 con.un. ($p > 0.05$) in the control group; in both groups it corresponded to "low" estimate, which was confirmed during individual analysis that demonstrated "low" estimates in all subjects of control group unlike group II with one "below average" and the rest – "low" estimates of functional state.

Conclusions

1. In former skilled and highly skilled track and field athletes continuing physical exercise training, unlike those conducting a sedentary way of life, some increase of autonomic nervous system parasympathetic impacts, a tendency to hypokinetic circulation type prevalence, absence of persons with hyperkinetic circulation type, greater number of "above average" and "below average" estimates of functional state index, and no differences in the body mass index between the period of sports engagement and the time of study have been revealed.

2. Former athletes conducting a sedentary life style after withdrawal from competitive sport more

frequently have eukinetic circulation type. They are characterized by apparent increase of autonomic nervous system sympathetic link and prevalence of "low" estimate of functional state. Their current value of the body mass index is significantly higher than that during the period of active sports engagement.

3. Functional state of former athletes continuing physical exercise training after termination of sports career is higher as compared to the ones of now sedentary former athletes and persons never engaged in any type of physical training, thus, indicating an expediency of continuing strictly individual physical exercise training after withdrawal from competitive sport.

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KARJERĄ BAIGUSIŲ LENGVAATLEČIŲ FIZINIS DARBINGUMAS IR CENTRINĖS HEMODINAMIKOS BEI AUTONOMINĖS NERVŲ SISTEMOS FUNKCINĖ BŪKLĖ

***Prof. dr. Evgeny Mikhalyuk*[1], *prof. dr. Larisa Gunina*[2]**
Zaporožės valstybinis medicinos universitetas, Ukraina[1],
Ukrainos nacionalinis kūno kultūros ir sporto universitetas[2]

SANTRAUKA

Straipsnyje pateikiama 24 didelio meistriškumo sportininkių, kurios jaunystėje bėgo trumpųjų nuotolių – 100–400 m – distancijas, kompleksinių funkcinės būklės tyrimų duomenų analizė. Pirmąją tiriamųjų grupę sudarė 12 moterų, kurios baigusios savo sportinę karjerą ir toliau buvo fiziškai aktyvios. Antrąją grupę taip pat sudarė 12 moterų, kurių fizinis aktyvumas pasibaigus aktyviai sportinei karjerai buvo mažas arba jo iš viso nebuvo. Abiejų grupių moterų sportinis meistriškumas sportinės karjeros laikotarpiu buvo panašus. Kontrolinę grupę sudarė 12 moterų, kurios jaunystės metais nesportavo, o šiuo laikotarpiu nėra pakankamai fiziškai aktyvios.

Širdies veiklos vegetacinės reguliacijos tyrimui taikyti širdies ritmo variabilumo analizės matematiniai metodai. Pagrindiniai centrinės hemodinamikos rodikliai buvo nustatyti automatizuotos tetrapoliarinės reografijos metodu toliau apskaičiuojant sistolinį ir minutinį kraujo tūrį, sistolinį ir širdies indeksą bei periferinį kraujagyslių pasipriešinimą. Fiziniam darbingumui nustatyti taikytas submaksimalaus krūvio testas PWC_{170}, krūvį atliekant veloergometru.

Tyrimo rezultatai parodė, kad sporto veteranių, gyvenančių fiziškai aktyvų gyvenimą, autonominės nervų sistemos parasimpatinė reguliacija yra padidėjusi, hipokinetinė kraujotaka dominuoja prieš hiperkinetinį kraujotakos tipą. Tarp tiriamųjų buvo daugiau moterų, kurių funkcinės būklės indeksas buvo vertinamas „didesnis nei vidutinis“ ir „mažesnis nei vidutinis“, jų kūno masės indekso rodikliai mažiau skyrėsi, kai jos sportavo ir pastaruoju metu. Tyrimo duomenys parodė. kad sporto veteranių, kurios nutraukė sportinę karjerą ir gyveno mažai fiziškai aktyvų gyvenimą, autonominės nervų sistemos simpatinės reguliacijos aktyvumas buvo didesnis, dažniau pasitaiko normokinetinis kraujotakos tipas. 91,7 % sportininkių turi „žemą“ funkcinės būklės vertinimą ir patikimai didesnį kūno masės indeksą dabar, palyginti su tuo, kurį turėjo aktyviai sportuodamos.

Stebima anksčiau nesportavusių ir dabar fiziškai neaktyvių kontrolinės grupės asmenų, palyginti su dabar fiziškai aktyviomis sporto veteranėmis, patikimai didesnė simpatinės reguliacijos dominantė, rečiau pasitaiko hipokinetinė kraujotakos reguliacija ($p = 0,007$), mažesnis fizinis darbingumas ir funkcinės būklės indeksas. Lyginant antros sporto veteranių ir kontrolinės grupės tiriamųjų duomenis skirtumų nenustatyta. Praėjus po aktyvios sportinės karjeros pabaigos 21,36 ± 3,6 metų tarp pirmos grupės sporto veteranių stebima tik kūno masės indekso padidėjimo tendencija 3,9 % ($p > 0,05$), o antros grupės veteranių ir kontrolinės grupės narių šis rodiklis padidėjęs vidutiniškai 13,9 ir 27,1 %. Funkcinė sporto veteranių, palaikančių didesnį fizinį aktyvumą, būklė, palyginti su vėliau visiškai nutraukusiomis fizinį aktyvumą, yra geresnė. Tai leidžia teigti, kad nutraukus sportinę karjerą yra tikslinga gyventi fiziškai aktyvų gyvenimą.

Raktažodžiai: sporto veteranės, lengvoji atletika, širdies ritmo variabilumas, centrinė hemodinamika, autonominė nervų sistema, fizinis darbingumas.

Evgeny L. Mikhalyuk
Home Address : 33/32, Yubileyny Av., Zaporozhye, Ukraine
E-mail: evg.mikhalyuk@gmail.com
Mobile phone: +38(097)39-40-590

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