Prediction of adverse changes in the functional state of the heart in junior athletes

UDC 796.01:612

PhD **A.S. Kryuchkov**[1]
PhD **M.A. Dikunets**[1]
G.A. Dudko[1]
E.V. Buchina[1]
[1]Federal Scientific Center of Physical Culture and Sport (VNIIFK), Moscow

Corresponding author: kriuchkov.a.s@vniifk.ru

Abstract

Objective of the study was to evaluate the prognostic significance of markers for the early diagnosis of cardiac overstrain.

Methods and structure of the study. A survey was made of an athlete of the Russian junior national cross-country skiing team (18 years old, 175.5 cm, 68.2 kg, 6 years of experience), who complained of low performance, which had been going on for the past few months. Functional testing of the athlete was carried out on a h/p/cosmos venus 200/100r running treadmill (h/p/cosmos sports & medical gmbh, Germany) with registration of oxygen consumption using the MetaMax 3B ergospirometry system (Cortex, Germany). Before and after the treadmill test, a standard 12-lead ECG was recorded on a Cardisuny C300 electrocardiograph, Fukuda Denshi, Japan. Analysis of blood samples taken by venipuncture was performed on analyzers cobas c 311 and cobas e 411 (Roche, Germany) and an ultrafast liquid chromatography-mass spectrometer with a triple quadrupole LCMS-8060 (Shimadzu, Japan).

Results and conclusions. The ECG after the treadmill test showed signs of a violation of the processes of repolarization of the posterior wall of the myocardium. Analysis of the activity of nonspecific markers and concentrations of cardiospecific proteins showed that the most sensitive, specific and prognostic marker for the detection of minor violations of the contractility of the left ventricle is the N-terminal polypeptide of natriuretic hormone.

Keywords: *cardiovascular system, heart strain, biomarker, predictive value, sensitivity.*

Introduction. Cross-country skiing, as a sport, places increased demands on the cardiovascular system (CVS) of athletes. At the same time, to maintain the speed of movement along the distance, skiers must have high aerobic capabilities of skeletal muscles. In particular, the most important element of tissue respiration and energy supply of muscle contractions is oxygen. In this case, the CVS is one of the leaders in ensuring its delivery to the working muscles of athletes [1]. Highly qualified skiers of the level of the Russian national team in laboratory conditions demonstrate high rates of maximum oxygen consumption, reaching 82–84 ml/kg/min, which indicates, among other things, the high functionality of the CVS in supplying working muscles with oxygen [8]. The stroke volume of the heart in professional skiers at rest reaches 100–140 ml, which is one of the necessary conditions for ensuring a high level of minute volume of blood flow, as well as economizing the work of the heart in extreme conditions of training and competitive activities.

The process of preparing skiers, starting from the stage of in-depth sports specialization, provides for the inclusion of an accentuated training effect, the purpose of which is to expand the functional capabilities of the CVS. In athletes involved in endurance sports, myocardial hypertrophy usually develops both due to the expansion of its cavities and due to thickening of the walls [7]. Unlike skeletal muscles, which are able to passively recover after the cessation of training exposure, the heart muscle never stops working throughout a person's life, developing tension and maintaining the body's vitality. In addition, when performing high-intensity loads, a diastolic defect can occur - a state of the heart muscle in which it does not have time to relax, as it needs to contract again [3]. A diastolic defect occurs, as a rule, at a heart rate (HR) exceeding 180 beats / min. Cardiac muscle cells at this level of heart rate begin to work under anaerobic conditions - they accumulate metabolic products and increase the level of free radicals [9]. The latter oxidize phospholipids and damage cell membranes, which ultimately provokes the death of cardiomyocytes and, as a result, myocardial dystrophy [5].

High-intensity loads pose a particular danger to the heart of young athletes aged 14-18, since the increase in heart volume at this age is significantly ahead of the increase in the diameter of the aorta, while due to the age-related increase in body length, the vessels are stretched and narrowed. In addition, the rate of growth of heart valves at this age stage of development of the body is inferior to the rate of change in the size of the myocardium, which leads to asynchrony in the work of the papillary muscles of the heart [2]. With such "immaturity" of the cardiorespiratory system, the heart of young athletes experiences increased stress when performing physical exercises, and especially when working in cyclic high-speed motor modes. All of the above makes increased demands on the control of changes in the state of the cardiovascular system in young skiers.

One of the varieties of such control is biochemical monitoring. The main requirements for it are the prognostic value and efficiency of obtaining biochemical parameters, which allow to identify and prevent possible negative changes in the cardiovascular system of athletes [6].

In our opinion, today, in pursuit of the efficiency and availability of obtaining biochemical parameters in the conditions of the training process, assessing the state of the athlete's CVS, the prognostic value of biomarkers, which allow identifying pre-pathological changes in this system of the body, has faded into the background. In particular, currently in the practice of biochemical monitoring, markers are used that do not allow one to unambiguously judge possible morphological changes occurring in the heart muscle, or have a weak sensitivity in response to functional overload of the myocardium. Therefore, their use for predicting a possible breakdown in the adaptation of the athlete's heart to the proposed loads is not possible. This hypothesis is confirmed by the literature data, which indicate the unequal prognostic value of biochemical markers that reflect the degree of myocardial tension in athletes.

Accordingly, for the timely diagnosis of preclinical manifestations of overvoltage, it is important to choose more informative and highly specific biochemical markers that respond to structural changes in the heart muscle of athletes.

Objective of the study was to evaluate the prognostic significance of markers for the early diagnosis of cardiac overstrain.

Methods and structure of the study. The observation involved an athlete of the Russian junior national skiing team (18 years old, 175.5 cm, 68.2 kg, 6 years of experience), who signed an informed consent to participate in the survey. The sportsman complained about low working capacity, which persisted for the last few months prior to the examination. He argued that an increase in the rest period between high-intensity loads within a weekly microcycle did not lead to the restoration of the level of physical condition. The study was approved by the ethics committee of the Federal Scientific Center of Physical Culture and Sport.

To assess the level and identify possible reasons for the decline in performance, the athlete was asked to undergo functional testing (step test) on a running treadmill h/p/cosmos venus 200/100r (h/p/cosmos sports & medical gmbh, Germany) with registration of the level of oxygen consumption at aerobic (AeT) and anaerobic (ANOT) thresholds using the Meta Max 3B ergospirometry system (Cortex, Germany). The initial running speed in the step test was 6 km/h for 2 minutes, then every subsequent minute it increased by 0.5 km/h at a constant treadmill blade inclination angle (10 degrees) until the athlete reached the level of ANOT. Before and after the stepwise test (5 min recovery), the functional state and autonomic orthostatic stability of the athlete's CVS were assessed by ECG diagnostics using a 12-channel Cardisuny C300 electrocardiograph (Fukuda Denshi, Japan).

Prior to functional testing, after a 12-hour fast and 24-hour absence of training, the athlete's blood was taken from the cubital vein into vacuum tubes with a clotting activator and a separator gel for biochemical analysis of serum (Greiner Bio One, Austria). The activity of AST, ALT, CPK and the concentration of CPK-MB, glucose, urea, triglycerides were measured on an automatic biochemical analyzer cobas c 311 (Roche/Hitachi, Japan). For the quantitative determination of myoglobin, N-terminal natriuretic hormone polypeptide (NT-proBNP), and troponin T (cTnT), a cobas e 411 automated immunochemical analyzer (Roche, Germany) was used. Quantitative determination of testosterone and cortisol was performed on an ultra-fast liquid chromato-mass spectrometer with a triple quadrupole LCMS-8060 (Shimadzu, Japan).

Results of the study and their discussion. The indicators of oxygen consumption at the power of AeT and ANOT were 56 and 68 ml/kg/min, respectively, which indicates a fairly high level of aerobic capacity of both slow and fast muscle fibers. The heart rate indicators for AeT and ANOT were 156 and 182 beats/min, respectively, and did not go beyond the limits of normal values for this athlete. It should be noted that at the level of ANOT, an athlete develops a heart rate at which a diastole defect can already be observed, and at the same time, such loads occur from one to three times in a weekly microcycle, and their duration ranges from 10 to 40 minutes of pure work time. In any case, under load, we did not reveal any deviations from the individual pulse corridors in the athlete. The characteristics of the ECG obtained before functional testing also did not reflect abnormalities in the work of the heart, however, after the stepwise test, signs of a violation of the processes of repolarization of the posterior wall of the myocardium were revealed.

Biochemical markers included in the stage comprehensive examination program: hemoglobin, hematocrit, testosterone, cortisol, urea, ALT, AST, CPK, iron, glucose, triglycerides and lactate, used to assess mechanical damage to skeletal muscle cells, features of metabolic adaptation under load, the depth of impact, the course of the recovery process and the level of training of the athlete did not go beyond the boundaries of the reference intervals established by us for this sport, which can serve as a criterion for the adequacy of the reactions of the athlete's body to loads. Analysis of the activity of non-specific markers (ALT, AST) did not reveal damage to skeletal muscle and liver cells, as well as a pre-pathological state of the skier's heart muscle under the influence of mechanical or metabolic stress.

The concentrations of cardiospecific proteins CPK-MB, myoglobin and cTnT did not go beyond the reference values, while the level of NT-proBNP was above the upper limit of the reference interval. The main stimulus for natriuretic peptide release is myocyte stretch and atrial volume overload, and the main signal for entry into the bloodstream is an increase in myocardial tension [4].

Conclusions. Despite the fact that the adaptation of the heart of athletes involved in endurance sports to the training load is associated with an increase in the thickness of the left ventricular wall, which is compatible with hypertrophic cardiomyopathy, for young athletes, increased heart stress can become a real threat of adaptation failure. Non-specific markers used in the program of stage complex examination of athletes do not allow characterizing the pre-pathological state of the heart muscle with sufficient reliability. At the same time, cardiospecific markers for detecting the presence of CVS overvoltage, which are widely used in laboratory diagnostics, have different sensitivities.

As a result of the study, we have shown that NT-proBNP, which is secreted in response to cardiomyocyte stress and reflects myocardial stress in the left ventricular wall, has the greatest prognostic significance.

Financing. The work was carried out within the framework of the state task of the Federal Scientific Center of Physical Culture and Sport (VNIIFK), No. 777-00026-22-00 (subject code No. 001-22/3).

References

1. Volkov N.I., Oleinikov Bioenergetika sporta [Bioenergetics of sports]. Moscow: Sovetskiy sport publ., 2011. 210 p.
2. Lyakso E.E., Nozdrachev A.D., Sokolova L.V. Vozrastnaya fiziologiya i psikhofiziologiya [Age physiology and psychophysiology]. Moscow: Yurayt publ., 2020. 396 p.
3. Meyerson F.Z. Adaptatsiya, deadaptatsiya i nedostatochnost serdtsa [Adaptation, deadaptation and heart failure]. Moscow: Medicina publ., 1978. 343 p.
4. Dorofeikov V.V., Sitnikova M.Yu., Lelyavina T.A. et al. Mozgovoy natriyureticheskiy peptid v kardiologii i kardiokhirurgii [Brain natriuretic peptide in cardiology and cardiac surgery]. Meditsinskiy alfavit. 2014. Vol. 1. No. 3. pp. 49-56.
5. Seluyanov V.N., Myakinchenko E.B., Gavrilov V.B. Sportivnaya adaptologiya. Fizicheskaya podgotovka v tsiklicheskikh vidakh sporta [Sports adaptology. Physical training in cyclic sports]. Moscow: TVT Divizion publ., 2021. 524 p.
6. Brancaccio P., Maffulli N., Buonauro R., et al. Serum enzyme monitoring in sports medicine. Clin. Sports Med. 2008. 27(1). pp.1-18.
7. 7. McCann G.P., Muir D.F., Hillis W.S. Athletic left ventricular hypertrophy: long-term studies are required. Eur. Heart J. 2000. 21(5). pp. 351-353.
8. 8. Myakinchenko E.B., Kriuchkov A.S., Adodin N.V., et al. One-year periodization of training loads of Russian and Norwegian elite cross-country skiers. J. Hum. Sport Exerc. 2021. 16(2). pp.701-710.
9. 9. Su Q.S., Zhang J.G., Dong R. et al. Comparison of changes in markers of muscle damage induced by eccentric exercise and ischemia/reperfusion. Scand. J. Med. Sci. Sports. 2010. 20(5). pp. 748-756.