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REACTION OF CARDIORESPIRATORY SYSTEM UNDER PHYSICAL ACTIVITIES OF DIFFERENT NATURE DEPENDING ON PHYSIOLOGICAL REACTIVITY AND FATIGUE

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Author contribution: A – study design; B – data collection;
C – statistical inference; D – manuscript production.

Abstract

Aim is to determine the peculiarities of cardiorespiratory system (CRS) reaction of qualified sportsmen under physical activities of different nature of power-generation proceeding from the principle of «power relations» connected with physiological reactivity of organism.

Methods. Research involving qualified sportsmen, and the members of National athletics team of Ukraine. The methods of complex testing of CRS physiological reactivity characteristics towards hypercapnic (CO_2-H^+) changes of respiratory homeostasis during resting period and performing test physical activities were used.

Results. Positive relation was revealed between cardiorespiratory system sensitivity to hypercapnic stimulus and development of functional reaction level and speed under aerobic workout of medium intensity, as well as negative correlation under long-term aerobic workout of maximum intensity. Inverse relation was determined between CRS sensitivity to hypercapnic stimulus and the level of efficiency and stability of functioning, as well as positive relation with the activity level of anaerobic processes in load energy generation.

Conclusions. The peculiarities of cardiorespiratory system (CRS) reaction of qualified sportsmen under physical activities of different nature of energy generation have been determined.

Keywords: reactivity, cardiorespiratory system, qualified sportsmen, hypercapnic changes of respiratory homeostasis, physical activities.

Introduction

In sports physiology the patterns of fatigue growth dynamics and phasing of recovery after intensive sports activities, training sessions and their series are the basis of studying the course of the process of adaptation of sportsmen's organisms to variable conditions of sports activity, also preferable focus of physical activities is taken into account [10, 11, 13].

It is known that the range of physiological reactions to irritants of different nature or intensity, and the "stimulus-reaction" correlation depend on age, functional state of the body, and its fitness level [1, 5]. Due to accommodative response (reactivity) common for an organism these changes are the reason of adaptative changes affecting the intensity of the process of homeostasis preservation during growing impact of an irritant – physical activity [2, 4, 7, 11]. Therefore, the process of adaptation of sportsmen's organisms to intensive physical activities is possible to describe using the concept «physiological reactivity», and using the changes of physiological reactivity during performing physical activities.

In the sports of the highest achievements, under perimaximal realization of functional capacities of the systems of organism, individual peculiarities of organism reactivity come out with not only the range of reactions to physical activities, but also different speed of their change under repeated

physical activities during training session [11, 13]. Besides, the nature of these changes and their speed is likely to depend on irregularity of physical activities and peculiarities of sports session overall. There is a good reason to believe that physiological reactivity changes having its complex characteristics considering both vegetative reactions and neurodynamic functions qualities can show functional capacity and individual nature of realization of organism power-generating capabilities under intensive physical activities, and are associated with nature of sports training session [6, 7, 12].

As part of experimental data analysis from these perspectives, appears the necessity of taking into account the type of physical reactivity leading to organism accommodation to effective execution of some kind of highly specialized activity demanding maximum manifestation of different sides of working power-generation [5, 9, 10, 13]. In any case, the interaction between organism and environmental irritant depends on the nature (intensity, duration) of impact, and on individual organism capacity to react to this irritant [11].

Particular relevance in sports physiology is gained by development of individual correction criteria, and orientation of adaptation process of qualified sportsmen to intensive work load on the ground of physiological reactivity changes of cardiorespiratory system (CRS) and considering the principle of «power relations» (the «stimulus-reaction» correlation).

The research was conducted due to fiscal research topic «Technology of assessment of risks of sportsmen's traumatism by electroneuromyographic and psychophysiological indicators» (State register № 0119U000307 of Ministry of education and science of Ukraine).

Research objective is to determine the peculiarities of cardiorespiratory system (CRS) reaction of qualified sportsmen during physical activities of different nature of power-generation proceeding from the principle of «power relations» connected with physiological reactivity of organism.

Methods

In pre-contest period of preparation the research was conducted involving qualified sportsmen (sub-masters of sports-masters of sports), the members of the National athletics team of Ukraine (54 sportsmen).

The methods of complex testing of CRS physiological reactivity characteristics towards hypercapnic (CO_2-H^+) changes of respiratory homeostasis during resting period and performing test physical activities were used. The progressive CO_2-H^+-stimulation was created by the method of reverse breathing in «bag in the box» system, the operational system of which was filled with gas mixture with 50–60 % of O_2 in. As tests there were used physical activities of medium aerobic workout intensity with VO_2 52–55 % of VO_2max working rate, and the ones of maximum aerobic workout intensity with VO_2 80–93 % of VO_2max working rate performed at the treadmill LE-200 CE. To assess the CRS reaction to test activities there were used the ergospirometric complex "Oxycon Pro" ("Jager", Germany), and methodological approach of CRS physiological reactivity assessment [1, 9]. Kinetic characteristics of CRS reaction to test activities were determined considering the speed of the first part of reaction, its peak and stability.

The testing was conducted after one day of rest having standard nutrition system and water schedule. The sportsmen were aware of the tests content and agreed to conduct them.

Statistical processing of the results was conducted using the «Microsoft Excel» software program determining the main statistic indicators: arithmetic average value (M), mean square deviation (SD), coefficient of variation (CV, %), minimum and maximum values of a measurement in the sample, median value, etc.

Results and discussion

Preliminary studies conducted under progressive hypercapnic stimulation allowed revealing three groups of sportsmen being different in type of CRS reaction to the CO_2-H^+-stimulus [5, 11]. Thus, among the qualified sportsmen-sprinters there was defined the type of reaction corresponding to the concept of hyperkinetic type, and characterized with fairly *high sensitivity level* and overall reactivity of ventilatory and circulatory reactions (rV_E/rP_ACO_2 2,27±0,16 l min^{-1}mm m.c.$^{-1}$) to CO_2-H^+-stimulus. Among long distance runners *lower sensitivity level* of CRS to CO_2-H^+-stimulus (rV_E/rP_ACO_2 1,09±0,14 l min^{-1}mm m.c.$^{-1}$) was distinguished,

corresponding to the concept of hypokinetic type of reaction to hypercapnic and hypoxic changes of respiratory homeostasis.

Among the sportsmen with the reduced level of CRS sensitivity to CO_2-H^+-stimulus (group III) under aerobic workout of medium intensity there was indicated fairly reduced level of CRS reaction by the level of lung ventilation (V_E), O_2 consumption (VO_2), and heart rate (HR) constituting 82–94 % from average data for all the sportsmen considered as 100 % ($p<0,05$). Under physical activities of maximum intensity aerobic workout high level of physical working capacity was provided probably by a higher speed of O_2 consumption (VO_2 122,16±2,18 %), and a level of lung ventilation (V_E 117,77±2,09 %). Besides while performing activities with different aerobic workout intensity among the sportsmen with reduced level of physiological reactivity there was indicated a higher level of lung ventilation efficiency by the amount of ventilation equivalent for O_2 (EQO_2 91,02–97,13 %), and cardiac cycle efficiency (O_2-rate 121,34–124,96 %).

The coefficient of functional stability (CFS) value for the HR «drift» and ventilation equivalent for O_2 under activities of medium (CFS HRst 70,22±6,03 %, CFS EQO_2st 72,85±5,84 %) and maximum (CFS HRcr 76,14±6,39 %, CFS EQO_2cr 69,94±6,82 %) aerobic workout intensity showed higher stability of functional reactions during long-term loads among the individuals with reduced level of CRS sensitivity to CO_2-H^+-stimulus which went with reduced level of respiratory compensation of metabolic acidosis, what was shown collaterally by firmly reduced level of CO_2 provision (VCO_2 82,19–83,76 %) as well as gas exchange ratio (VCO_2/VO_2 82,02–93,79 %).

Among the individuals with high level of CRS sensitivity to CO_2-H^+-stimulus, on the contrary, under physical activities of medium aerobic workout intensity there was observed higher level of CRS reaction by the level of lung ventilation, O_2 consumption, and heart rate (the indicators were changing within 103,49–126,76 % from average data taken as 100 %). Under activities of maximum aerobic workout intensity the reduced level of physical working capacity went with the reduced level of CRS reaction (V_E 83,29±5,09 %, VO_2 79,13±5,73 %). At the same time, without regard to the level of cardiorespiratory system reaction by V_E, VO_2 and HR, performing test loads was always accompanied with higher level of respiratory compensation of metabolic acidosis (VCO_2 116,29–127,41 %, VCO_2/VO_2 112,96–123,78 %) under activities of different workout intensity, as well as with reduced level of efficiency and stability (CFS HR 123,96–130,38 %, CFS EQO_2 137,47–143,88 %) of cardiorespiratory system functioning.

Consequently, among the sportsmen with fairly reduced level of CRS sensitivity to CO_2-H^+-stimulus together with greater irritant impact (physical activity intensity) the level of physiological reaction of cardiorespiratory system was becoming greater under physical activities of different nature of power-generation. At the same time, high level of organism physiological reactivity to respiratory homeostasis changes in resting period combined with high level of physiological reaction of cardiorespiratory system under irritant impact of weak intensity (aerobic activity of low and medium workout intensity) and reduced level of reaction to irritant impact of strong intensity (aerobic activities of maximum workout intensity).

Under balanced load of medium aerobic workout intensity (VO_2 52–55 % from VO_2max) a high speed of development of functional reactions assessed by half-time reaction of O_2 consumption increase ($T_{50}VO_2$, sec) was observed among the sportsmen with high level of physiological reactivity ($T_{50}VO_{2CT}$ 75,01±7,16 %), and the lowest speed of development of functional reactions was inherent for the sportsmen with reduced level of CRS sensitivity to CO_2-H^+-stimulus ($T_{50}VO_2$st 125,91±9,71 %). With increasing the workout intensity of physical activity (maximum aerobic workout intensity with VO_2 86–93 % from VO_2max) higher mobility was observed among the sportsmen with reduced level of CRS sensitivity to CO_2-H^+-stimulus ($T_{50}VO_2$cr 80,95±4,12%).

This meant that under activities of medium aerobic workout intensity high level of CRS sensitivity to CO_2-H^+-stimulus, as in the case with sportsmen-sprinters, caused a rapid reaction of CRS to blood acid-base balance, and under long-term activity of maximum aerobic workout intensity reduced CRS sensitivity to hypercapnia among long distance runners enhanced mobilization and not suppression of speed of development of functional

reactions under increasing acidosis degree and fatigue.

The differences between CRS reaction while performing physical activities of different workout intensity revealed among the individuals with different level of physiological reactivity were analyzed proceeding from the principle of «power relations» [3]. Among the individuals with high level of CRS sensitivity to CO_2-H^+-stimulus having medium intensity irritant impact, as it was under physical activity of medium aerobic workout intensity, a higher level of corresponding reaction was observed, and with increasing the irritant intensity (activities of maximum aerobic workout intensity) the level of corresponding reaction was decreasing. Similar correlation «stimulus-reaction» can occur among children and teenagers, whilst the decrease of response to increasing irritant intensity was explained by exhaustion of functional reserves of the body [3]. In this case, among the sportsmen occur the correlations connected with the level of CRS physiological reactivity and show the specificity of system accommodation for effective realization of its capabilities under manifestation of highly specialized working capacity at short competitive distances, and realization of anaerobic energy potential of sportsmen's organisms for this.

Among the sportsmen with reduced level of physiological reactivity to irritant impact of medium intensity a reduced level of corresponding CRS reaction was observed, and with increasing the irritant intensity there was an increase of the level of corresponding reaction. Decreasing of CRS reactions sensitivity to CO_2-H^+-stimulus in this case shows an increase of its functional capabilities, and the degree of such decrease of sensitivity to CO_2 is closely related to increasing of maximum level of O_2 consumption and some other manifestations of maximum capabilities of cardiorespiratory system as well as physical working capacity under activities of maximal aerobic workout intensity. According to literary data, reduced response to irritation of medium intensity and maximal reaction to extreme stimulus are inherent to individuals with good physical fitness and sportsmen with high sports working capacity [1, 5, 9, 11] under physical activities demanding total endurance manifestation.

Consequently, sportsmen with different level of physiological reactivity of cardiorespiratory system to respiratory homeostasis changes were distinguished with different ratio of «stimulus-reaction». A positive correlation was observed between characteristics of sensitivity and overall reactivity of CRS to CO_2-H^+-stimulus with the level of CRS reactions and the speed of their development under aerobic activities of medium workout intensity (VO_2 52–55 % from VO_2max), and a negative correlation with the level of cardiorespiratory system reaction under physical activities of maximum aerobic workout intensity (VO_2 86–93 % from VO_2max). Opposite nature of correlation was observed between the level of sensitivity and reactivity of cardiorespiratory system to respiratory homeostasis changes in resting period and indicators characterizing the level of efficiency and stability of functioning systems, as well as positive correlation with indicators of specific weight of anaerobic glycolytic processes in power-generation of physical activity of both medium and maximal aerobic workout intensity.

Consequently, in the course of long-term adaptation of organism to sports activities the nature of optimization of CRS physiological reactivity (sensitivity and stability) to respiratory homeostasis changes occurs. This can act as a mechanism of development of workout intensity of respiratory compensation of metabolic acidosis which would provide efficiency of the main factors determining the level of physical working capacity and energy processes under competitive activities with different correlations of aerobic and anaerobic processes in their power-generation.

These findings confirm that specialized development of different variants of load power-generation influences CRS reactive features and are indicative of modification of cardiorespiratory system role during adaptation to activities of different power-generating nature – the correlation of its role in oxygen provision to working muscles and their «clarification» from metabolites changes. Such modification is to increase sensitivity and overall CRS reactivity to CO_2-H^+-stimulus, and acidemia during performing velocity-strain training loads of anaerobic nature, and to decrease sensitivity during use of training means aimed to develop aerobic capabilities and increase the level of overall endurance of sportsmen.

Conclusions

1. Qualified sportsmen with different types of physiological reactivity (by sensitivity and stability of cardiorespiratory system reaction to adequate humoral stimuli) specialized in competitive distances different in time needed for their completion are distinguished by different correlations in «stimulus-reaction» under physical activities of different nature.

2. High level of organism physiological reactivity determines high level of CRS reaction under impact of irritant of weak intensity (activities of low and medium aerobic workout intensity) and reduced level of reaction to impact of irritant of strong intensity (activities of maximal aerobic workout intensity) leading to more rapid reaction of cardiorespiratory system at initial part of physical aerobic activity of medium workout intensity, and reduced one – under activity of maximal aerobic workout intensity.

3. Among the sportsmen with reduced level of physiological reactivity more distinct reaction occurred during a lot stronger irritant intensity combining with reduced speed of functional reactions development during activities of medium aerobic workout intensity. Reduced sensitivity of cardiorespiratory system reactions to hypercapnia among long distance runners promoted mobilization of their aerobic capabilities longer periods without suppression of speed of development of functional reactions under long-term activities of maximal aerobic workout intensity.

4. In the course of long-term adaptation of organism to sports activities a particular nature of physiological reactivity optimization (sensitivity and stability) of CRS to respiratory homeostasis changes occurs. This can act as a mechanism of development of workout intensity of respiratory compensation of metabolic acidosis which would provide efficiency of the main factors determining the level of physical working capacity and energy processes under competitive activities with different correlations of aerobic and anaerobic processes in their power-generation.

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