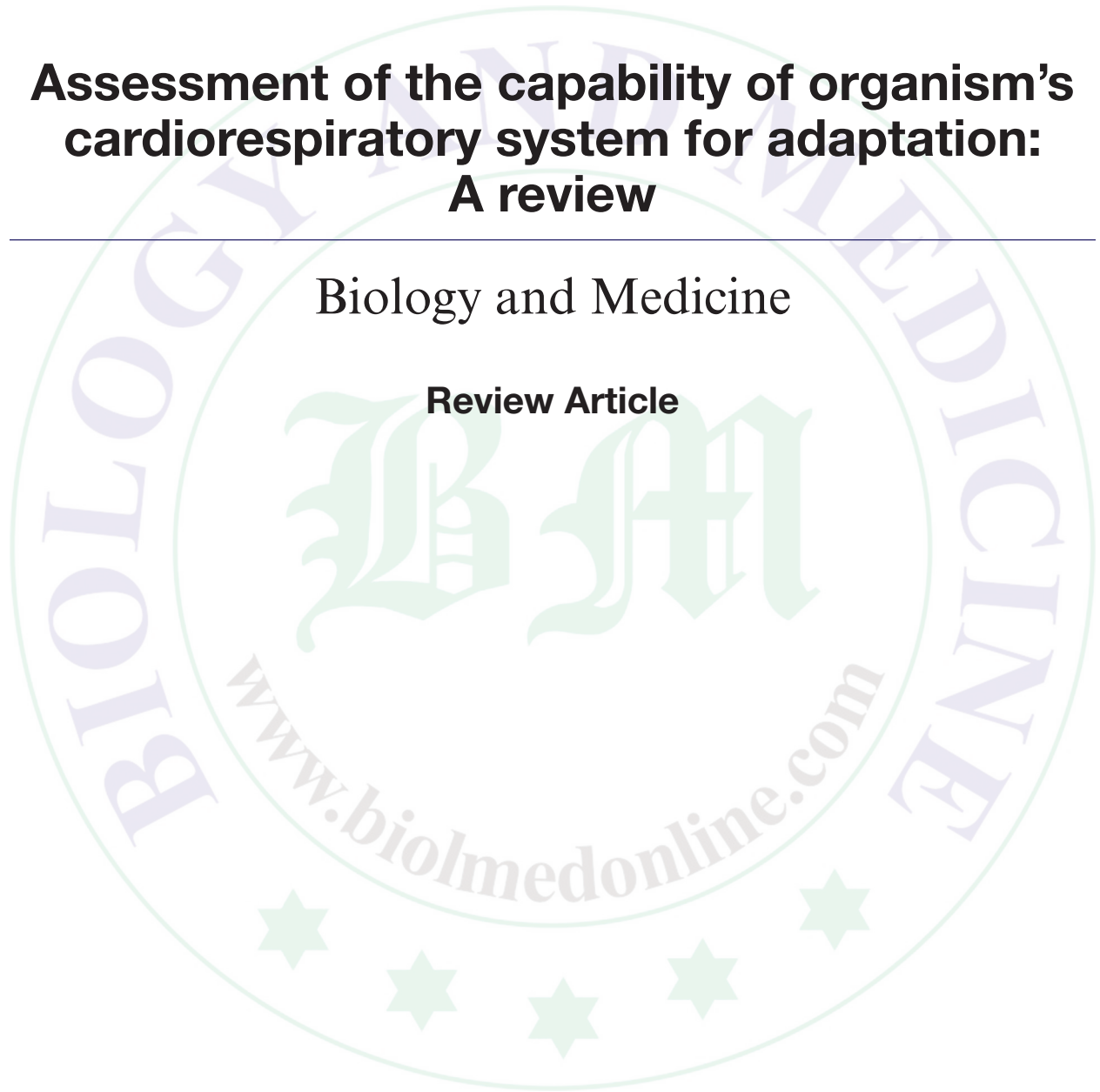


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Assessment of the capability of organism's cardiorespiratory system for adaptation: A review

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Abstract

Active self-fulfillment of a human in the modern society requires high level of individual health. Health is both personal and social value. The way of life facilitates maintaining the healthy state of an organism (50% according to WHO). Both practitioners and the person himself require for self-assessment appropriate diagnostics determining how the current lifestyle provides for individual health, of which the leading factor is the state of the cardiorespiratory training to adapt the organism to constantly changing environmental conditions. To address the issue, the authors have performed an analysis of literature, and developed and suggested in the public domain the "Potential of the Cardiorespiratory System Evaluation Recommendations" program presented at the "Health Workshop by Ustinova" (<http://ustinova-zdorovie.ru/>).

Keywords: Individual health; cardiorespiratory training to adapt; state diagnostics; recommendations for health promotion.

Introduction

For active self-fulfillment of a human in the modern society, not only narrow professional knowledge and skills but also the high level of individual health are important. Thus, health is both personal and social value. It is the way of life of a person that more than anything (by 50% according to WHO) helps to maintain the healthy state of the organism or adds to the loss of health. One of the leading risk factors and the main reason of primarily cardiovascular diseases, as well as a number of infectious diseases, diabetes mellitus type 2, and some types of cancer are the imbalance of consumption (nutrition) and expenditure (physical activity) of energy [1]. Approaches to nutrition and physical activity of a human are regulated by the way of life. Apparently healthy people [2-8], in order not to join the category of ill people, need screening examinations for arrangement of disease prevention. To do this, practitioners need relevant diagnostics of determination how current lifestyle of a person provides for his personal health. Affordable and effective diagnostics of the same orientation are needed by the person for assessment of the state of health and motivation to change his lifestyle.

Body of the Work

An organism is aggregate activity of functional systems. At the tissue level, the most important life support system is the functional system of gas exchange and acidity regulation. Acidity of the blood is a hard constant, and when pH of the internal environment changes, it is normalized by changing the activity of the respiratory and cardiovascular systems (CVSs) [9]. It is the performance of the cardiorespiratory system that maintains homeostasis of the organism in constantly changing environment. The authors [10,11] revealed the directly proportional relationship between physical activity, cardiorespiratory training, and self-assessment of health of men and women of different age groups. In all groups of mostly healthy people, the higher the physical activity is, the better the cardiorespiratory training and the self-esteem are, and vice versa. Aerobic testing (inhale delay values – the Stange's test, exhalation – the Hench's test, the vital capacity of lungs) shows further the relationship of the respiratory muscle function and obesity [12,13]. Evaluating the performance of arterial blood circulation velocity and the value of changes in the blood pressure (BP),

both at rest and during acute mental stress, comparing the obtained values with the body weight index (BWI), the authors [14] identified the cardiovascular disease risk factors – these are depression, low self-esteem, and obesity. The authors [15] showed that obesity can neutralize the benefits of physical activity, even for healthy population of men and women. British scientists considered the risk of development of cardiovascular diseases depending on the professional and social classes. The priority risk factors for all of them are the increased systolic BP and the BWI [16]. Comparing the severity of the coronary heart disease (CHD) and the cardiorespiratory and functional training of the CVS, the authors [17-20] revealed an inverse relationship – the higher the cardiorespiratory training is, the weaker the manifestations of the coronary artery disease are. The authors' studies [21] of the state of the compensatory-adaptive reserves of people living in extreme conditions in the Northeast of Russia showed that it is the CVS that is the main indicator of the functional state of an organism. The need for maximum focus on prevention of diseases of the CVS is confirmed by the forecasts of increasing number of productive years of life lost because of these diseases for the period of 2000-2030: South Africa – by 28%, China – by 57%, Brazil – by 64%, India – by 95%, USA – by 20%, and so on [22]. Many authors focus on the state of the cardiorespiratory function during aging, as with the increase in life expectancy, sharp growth of frequency of the circulatory system diseases is observed. Therefore, changes in the circulatory and respiratory functions determine the intensity of the aging process [23]. The above confirms that the following is important for assessment of cardiorespiratory training: (1) Aerobic testing. (2) Determination of the value of deviation from the normal body weight. (3) Finding affordable and objective quantification of the cardiorespiratory reserve of the organism.

(1) Aerobic testing: The capability of the respiratory system is determined by the vital capacity of lungs (VC, l): three maximum exhalations are made in the spirometer and the best result is recorded. The data obtained are compared with the proper lung capacity (PVC):

$$\begin{aligned}PVC_{\text{men}} &= (H \cdot 0.052 - CA \cdot 0.022) - 3.60 \\PVC_{\text{women}} &= (H \cdot 0.041 - CA \cdot 0.018) - 2.68,\end{aligned}$$

where H is the height, cm; CA is the chronological age, years. Percentage deviation Δ_{VC} :

$$\Delta_{VC} = VC \cdot 100\%/PVC$$

Increase in the actual value of VC relative to the proper one indicates the high morphological and functional capacity of lungs [24]. The development of external respiration (providing them with body weight) is determined by the life index (LI): $LI = VC/W$, where VC is in ml, W is the weight in kg (normal LI: men – more than 60 ml/kg, women – 50 ml/kg) [25]. Use of these parameters requires a spirometer and is difficult to diagnose unassistedly.

Researchers [26] found that short-term reduction of the oxygen content (hypoxia) and increase in the level of the carbon dioxide content (hypercapnia) in the absence of adverse effects allows to stimulate the activity of the antioxidant system, reduce stress, improve performance, and accelerate the processes of recovery after physical and mental exertion, thus improving the quality of life. Accordingly, the higher the organism's capability of hypoxia and hypercapnia is, the higher the health reserve is. To control the tropism of the organism to hypercapnia Buteyko suggested the breath holding test (apnea) at expiration ($A_{\text{exhalation}}$, s). The normal value of the $A_{\text{exhalation}}$ pause is 60 s or more, less than 60 s is a disorder. He considers 5 degree of pathology: the first degree – less than 50 s, the second degree – less than 40 s; the third degree – less than 30 s; the fourth degree – less than 20 s, the fifth degree – less than 10 s. Less than 5 s was defined as the "life margin". Currently, the Hench's test is very popular to control the $A_{\text{exhalation}}$ value [4,26]. In order to define the body's resistance to excessive carbon dioxide, the stability index (SIC) is determined: $SIC = HR_r/A_{\text{exhalation}}$, where HR_r is the heart rate at rest, beats/min. The normal value of SIC is 1 (point) or less. The lower the ratio is, the higher the persistence of the organism to excessive CO_2 is [24]. Comparing SIC values to the values of Buteyko, we find: the first degree pathology is if SIC is equal to 1-1.19; second – 1.2-1.49; third – 1.5-1.99; fourth – 2-2.99; fifth – 3-5.99. If the value is between 6 and 11.9, it is the unacceptably low persistence. Less than 12 s is the "life margin". The $A_{\text{exhalation}}$ and SIC indicators are simple, objective, and easy for self-diagnostics of the cardiorespiratory function persistence state.

(2) Determination of the value of the body weight deviation from normal values: Estimated deviation (Δ_{Wv} , %) of the actual body weight (W , kg) of the expected weight (EW , kg): $\Delta_{Wv} = W/EW \cdot 100\%$, where EW , kg is determined by the formula [27] with account of the ratio of P , cm and HF , yrs:

$$EW = 50 + 0.7 \cdot (H - 150) + \frac{CA - 20}{4}$$

Using the BWI , we can find out to what level of disorders the individual body weight relates: BWI , where W (kg), H (m). $BWI = W/H^2$ standard values: less than 18.5 – underweight; between 18.5 and 24.9 – normal value; between 25 and 34.9 – first degree of obesity; between 35 and 39.9 – second degree of obesity; 40 and more – third degree of obesity, the nasty form.

(3) Quantitative determination of the cardiorespiratory reserve of the organism. The elastic properties of arteries deteriorating over age (sclerotic changes, reducing the number of smooth muscle cells of the wall, etc.) increase the BP and reduce the adaptability of the blood circulatory system to functional loads and pathological processes [28]. Therefore, the most important indicators of the state of the CVS , according to many authors, are the systolic (SP), diastolic (DP), and pulse (PP) BP , heart rate at rest (HR_r), and after standard loading; the stroke volume, the minute volume of blood (MVB), as well as various combinations of these parameters. These parameters are linked to calendar age (CA), height (H), body weight (W), as well as the possibilities of the respiratory system – the exhalation apnea ($A_{\text{exhalation}}$), the vital capacity (VC), and so on [9,13,17,18,21,24,29-33].

The authors [29] revealed that the main markers of chronic reduction in physical performance, as well as in the functional state of the central, autonomic nervous and CVS s are: HR_r , SP , PP , the Rufe index (RI). The growing/declining capacity of the functional state of the CVS and the stamina to physical activity is estimated using the simple and very indicative Rufe test: the examined person stands still, they count his pulse rate (P_1) for 15 s; then he performs 30 squats during 1 min; then they count the pulse rate for the first (P_2) and last (P_3) 15 s of the first minute of recovery. The RI is calculated by the following formula:

$$RI = \frac{4 \cdot (P_1 + P_2 + P_3) - 200}{10}$$

Endurance of the CVS to the load on the RI : less than 5 – “excellent” (trained people and athletes); less than 10 – “good”; less than 15 – “satisfactory”; more than 15 – “poor”; more than 20 – “unacceptably poor” [32,34-39].

When it is not possible to perform the squats test to assess the degree of fitness of the CVS to perform physical activity, the ratio of endurance ($PAER$) is used

$$PAER = HR_r \cdot 10/PP$$

The normal value of $PAER$ (at the normal $HR_r = 60-80$ beats/min): 12-16 conv. units. The growth of the $PAER$ caused by the PP decrease is a sign of the detraining CVS ; and the decrease in $PAER$ is a sign of fatigue [32].

Reduction of the adaptive capacity is accompanied by increasing stress of the regulatory systems. The express method of diagnosing the stress at regulation of the CVS is the determining the type of the blood circulation self-regulation ($TBCSR$):

$$TBCSR = DP/HR_r \cdot 100\%$$

The value of the $TBCSR$ equal to 90-110 describes the cardiovascular (normal, mixed) type of blood circulation self-regulation; below 90 – the cardiac type – the good quality of blood circulation is achieved by enhanced heart operation. The $TBCSR$ above 110 is the vascular type of blood circulation self-regulation, indicating the economization of functional reserves, but dangerous, with the threat of vascular forms of primary hypertension [32,33].

The MVB (l/min, ml/min) – the amount of blood pumped by heart per minute. The MVB describes the state of the mechanical function of the myocardium, which reflects the state of the circulatory system. The normal value of the MVB at rest has a wide range: between 3.5 and 5.0 ltr. The method of finding the MVB by the Starr's formula: $MVB = SV \cdot HR_r$, where SV is the systolic blood volume, ml: $SV = 90.97 + 0.54 \cdot PP - 0.57 \cdot DP - 0.61 \cdot CA$ [32].

Conclusion

The reserve of person's living resources, his ability to withstand extreme stress and resist diseases describes the reserves and the quality of health [40]. The simple and indicative indexes for

evaluation and self-assessment of their capabilities are: VC compared to the PVC, LI, $A_{\text{exhalation}}$, SIC; W compared to EW, BWI; RI, PAER, TBCSR, and MVB. Regular physical activity improves the vascular endothelial function, reduces their peripheral resistance, increases the efficiency of the circulatory apparatus function, and increases the reserves of the cardiorespiratory system [28]. To control the quality and efficiency of the training load, in order to avoid over-training [4], the value of the optimal pulse rate (HR_{loaded}) with account of the gender attributes is calculated [30]:

$$HR_{\text{loaded(men)}} = (205 - 0.5 \cdot CA) \cdot 0.8$$

$$HR_{\text{loaded(women)}} = (220 - CA) \cdot 0.8$$

In order to identify the quality of the daily exercise and prevent overtraining, it is important to measure the values of HR_{loaded} (beats/min) and PP_{loaded} (mm Hg) at the peak of the load and calculate the integral blood circulation efficiency index (BCEI, points): $BCEI = PP_{\text{loaded}}/HR_r$ [31]. BCEI during training must be maintained approximately constant.

Summary

For evaluation and self-assessment of reserves of the cardiorespiratory system of the organism to adaptation in the changing environment, it is important to control the following parameters: VC compared to the PVC, LI, $A_{\text{exhalation}}$, SIC; W compared to EW, BWI, RI, PAER, TBCSR, and MVB.

1. Regular physical load is needed to improve the reserves of the cardiorespiratory system.

2. To provide for self-control of the quality of the training regular exercises, one needs to know his best value of HR_{loaded} during exercises, and in order to prevent overtraining, to control BCEI on the peak load.

3. The authors developed and offered in the public domain the program “The Potential of the Cardiorespiratory System Evaluation Recommendations” presented at the website of the “Health Workshop by Ustinova” (<http://ustinova-zdorovie.ru/>).

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