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# AGE DYNAMICS OF THE BODY'S FUNCTIONAL RESERVES

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**Abstract**

The study compared the results of the study of the body's functional reserve obtained by different methodological approaches (limit and dosed physical activity) and studied the possibility of using an original test for their assessment. For this purpose, a bicycle ergometric load with a change in power in a closed cycle (with reverse) was used, according to which about 30 criteria were obtained. The subjects were of different age, gender, physical fitness level and sports specialization (n= 354). Under the conditions of maximum and dosed physical activity, a number of indicators of physical performance, the level of functioning of the cardiovascular, respiratory, and central nervous systems, the state of the mechanisms of regulation and energy tension (activation) of the body were determined. The age dynamics of the criteria of functional reserves in males aged 7 to 22 years and their variability were determined. The use of statistical analysis made it possible to determine the normative values of physical performance indicators, heart rate, state of regulatory mechanisms and the degree of activation (stress) of the body under conditions of closed-cycle physical activity. The results of the study demonstrate the possibility of predicting the functional reserves of children and youth under the conditions of using dosed loads with reverse, in which the degree of reactions of the executive and regulatory systems correspond to the optimal level, and their graphical record takes the form of a hysteresis loop with four informative sections. The dependence between individual elements of the loop and functional capabilities (area, cross-section, angle of inclination, etc.) is established.
**Keywords:** *limit and dosed loads, functional reserves, children and youth*

## 1. Introduction

From the theoretical and practical point of view, the relevance of the considered problem is determined by the lack of agreed views on the tasks and basic provisions of functional diagnostics, which is known to be carried out in three states: a) in operational rest, under conditions of b) dosed and c) limit loads. However, of the more than 200 known methods for assessing the functional state (reserve capacity, adaptation reserves, functional capacity) of people involved in physical education and sports or those leading a sedentary lifestyle, none can claim absolute authenticity, reliability, informativeness, stability, etc., that is full compliance with the requirements of test standardization. Some of them are outdated [V. L. Karpman's data (1974) are more than 50 years old], but still serve as a reference point for many researchers. Others have received unsatisfactory ratings from experts and restrictions on their use (e.g., the Ruffier test); others need to be improved in terms of age, gender, and normative values [functional change index (Baevsky R., Bersenova A. et al. 2009)]; others, which use only heart rate (HR), are characterized by insufficient informational value (Bosenko A., 2017).

The fifth group includes functional tests that are accompanied by excessive tension of executive and regulatory systems, and therefore are recommended for use for persons with a high level of physical fitness under conditions of medical and biological support (Mykhaliuk Ye. L., 2007). Last, but not least, there are tests that require sophisticated equipment and appropriate training of the staff (Karpman V. L. et al., 1988).

There are also ambiguous approaches to functional reserves in terms of conceptual and terminological apparatus. Functional reserves are invariably called one of the most important components of human health or physical condition (Davidenko D. N., 2005; Apanasenko H. L., 2017). Functional reserves are the basis for optimal adaptive responses, high sports performance, and successful work, especially in conditions requiring the ultimate level of functioning of systems and the body.

In the early 80s, the problem of functional reserves (Mozzhukhin A. S., 1980) was formed in the physiology of work, sports, and later in age physiology (Bosenko A. I., Belinova, A. G., Tsoneva, T. N., 1997). As defined by A. S. Mozzhukhin (1980), “...the reserve capabilities of an organism are understood as its latent capabilities (acquired in the process of evolution and ontogeny) to increase the functioning of its organs and organ systems in order to perform extremely large work, to adapt to extraordinary changes in the external or internal environment of the organism”.

It is believed that the objective criterion of functional reserves of a person, in particular, a child, is the level of his or her physical performance. The most complete picture of functional reserves is given by physical performance data obtained during testing with limit loads - work to failure, especially in conditions of increased motivation (Mozzhukhin A. S., 1980; Bosenko A. I., 1986; Davidenko D. N., 2005).

We (Bosenko A. I., 1986; Bosenko A. I., Belinova, A. G., Tsoneva, T. N., 1997) have established the factor structure of functional reserves of children, adolescents and youth of different levels of fitness, developed model characteristics and prognostic formulas of physical performance reserves both for work in normal conditions and in conditions of increased motivation. The possibility of predicting physical performance (its reserve) for conditions of increased motivation, according to testing data in normal conditions, is shown.

Testing with the use of limit loads causes extraordinary shifts in regulatory and supporting systems (Karpman V. L. et al., 1988; Davidenko D. N., 2005; Mykhaliuk Ye. L., 2007), is quite complex, requires the fulfillment of special conditions and is associated with a risk to the health of the subjects. Such studies are especially difficult in childhood, which explains the insufficient study of the functional reserves of children and adolescents and the availability of very limited data in the scientific literature, presented in separate papers (Bosenko A. I., 1986; 2017; Kalynychenko I., 2016; Fedynyak N., Mytskan B., 2020).

*The aim of the* study is to investigate the level of a set of criteria for physical performance and the possibility of assessing functional reserves, according to their data, in children, adolescents and young people under conditions of limiting and dosed loads.

## Material and method

The study involved people of different ages, genders, fitness levels, and sports specializations (n=354), including 270 schoolchildren with an average level of physical activity and 136 athletes of different fitness levels

In the first series of studies, cyclic bicycle ergometric physical activity with a power of 70 % of the maximum under conditions of normal (NM) and increased (IM) motivation (competitive conditions) was used. When analyzing the existing methods of physical performance research, we took into account the relevance of the tests and their adequacy to the age characteristics of the subjects.

According to well-known experts (Karpman V. L. et al., 1988; Mykhaliuk Ye. L., 2007), one of the most objective methods of assessing the physical performance of children and youth is testing using a load whose power gradually increases. At the same time, the priority of continuously increasing (ramp) physical activity on a cycle ergometer is emphasized.

So, in the second series of studies, a method of testing the functional capabilities of the human body using physical activity that varies in a closed cycle (Davidenko D. N., 2005) was used. In this case, the load power continuously increases from zero to the required level at a constant rate (33 W/min), and then decreases to the initial level at the same rate. The load can be reversed either by power or by a certain level of heart rate. We chose the latter option as more physiological, since the reverse is carried out at the same heart rate for all subjects (155 beats/min). At the same time, the subjects achieved different load power. Graphical recording of heart rate dynamics depending on changes in load power during the full testing cycle due to the inertia of the cardiovascular system (CVS), took the form of a hysteresis loop (Fig. 1). According to the authors of the methodology, the heart rate dynamics under these conditions can be regarded as a generalized characteristic, since the analysis of the dependence of other indicators under similar conditions, for example, $O_2$, consumption, revealed general patterns. The simplicity of registration and popularity of such a parameter as heart rate determined the choice of this indicator in testing.

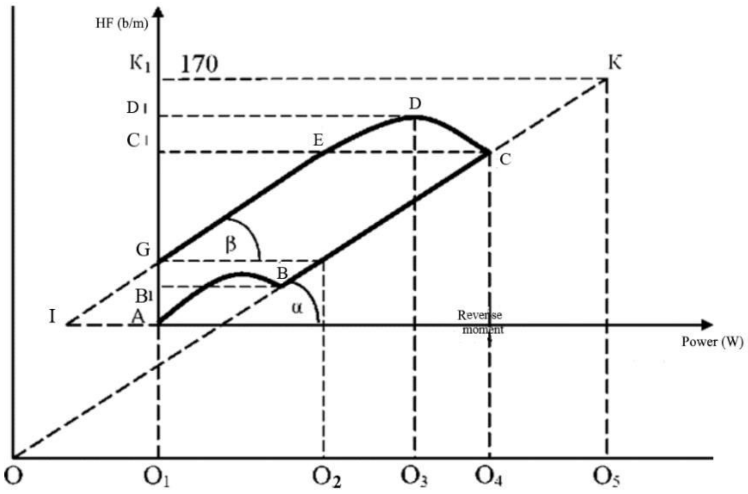


**Figure 1.** *Graphical representation of heart rate dynamics depending on changes in load capacity during the full testing cycle (hysteresis loop)*

Based on the results of automated analysis of the hysteresis loop parameters, 28 indicators were obtained, grouped into five groups, which were used as criteria for the formation of an individual profile and the prediction of the functional reserves of the subject.

**2.** In order to monitor the functional state (well-being) of the subject and to study the adaptive reactions of the executive and regulatory systems, the study was accompanied by a number of additional techniques: Assessment of brain general function using Loskutova's method; Omegametry; ECG; Variation pulsometry; Rheography and others.

## 3. Results and Discussions

Based on the results of the 1st series of studies, more than 80 variables were obtained, which were included in the above statistical analysis methods. As a result, regression equations were obtained that made it possible to predict reserves under conditions of NM and IM using 7 to 17 variables. Thus, limit loads confirmed their informative capacity in studying functional reserves of children, adolescents and youth. However, it is necessary to note an extremely tense level of functioning of both supporting and regulatory systems (Fig. 2). Under these conditions, the heart rate reached 200 beats/min, respiratory rate - 70 cycles/min, systolic blood pressure increased with the age of the subjects from 130 to 190 mm Hg. Diastolic pressure in trained subjects decreased, in some cases to zero (in 12 %), which reflected the phenomenon of infinite tone. Profound shifts were also noted in the state of the central nervous system, activation of sympathetic-adrenal mechanisms and suppression of parasympathetic influences.

These data, the low level of health of children and youth (Apanasenko H. L., 2017; Topchii M. S., 2018; Mykhaliuk, Y. et al., 2024), and cases of sudden deaths in physical culture and sports prompted the authors to look for other ways to diagnose the functional state and assess the adaptive reserves of the subjects. We conducted long-term longitudinal studies of schoolchildren and young people using dosed closed-cycle physical activity, which we based on an automated system (Bosenko A. I., 2003) The table below shows, as an example, the results of physical performance by a reduced number of criteria.

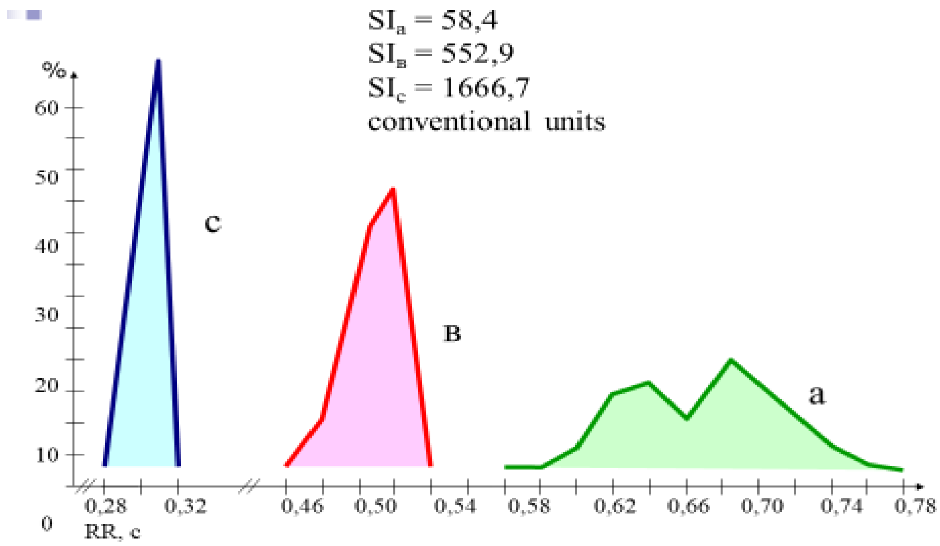


**Figure 2.** *The state of the heart rate regulation mechanisms of a young football player, according to SI data, in different phases of testing at maximum loads (a – initial state, c – 1st minute of recovery, b – 20th minute of recovery, according to Bosenko A. I., 1986)*

It is established that by the total time (T, s) and volume (A, kj) of the performed work, as well as by other indicators (reverse power – NR, $PWC_{170}$, $PWC_{170/kg}$) of working capacity, there is a progressive and reliable increase from 23.4% at 9–10 years old to 106.3% - at 15–16 years old. It is noticeable that smaller shifts are noted in relative indicators of work capacity $PWC_{170/kg}$, which is explained by the increase of body weight of the examined with age.

***Table 1.*** *Dynamics of physical performance of boys from 7 to 16 years old, according to the data of closed-cycle load testing (with reverse)*

| Groups / Indicators | 7–8 years, n=50 | 9–10 years, n=26 | 12–13 years, n=21 | 14–15 years, n=19 | 15–16 years, n=18 |
|---|---|---|---|---|---|
| | M±m | M±m | M±m | M±m | M±m |
| T, s | 288.0±8.6 | 355.1±17.4** | 374.48±11.9** | 482.1±20.9**♥ | 594.4±14.2**♥ |
| A, kj | 9.02±0.55 | 16.84±1.62** | 20.37±1.2** | 29.9+4.49**♦ | 48.4±5.4**♦ |
| NR, W | 74.1±4.43 | 90.61±2.95** | 96.24±3.06** | 124.1±0.87**♥ | 163.35±3.3**♥ |
| $PWC_{170}$, W | 74.55±3.45 | 112.5±5.1** | 123.96±5.2** | 157.7±7.33**♠ | 204.18±9.7**♠ |
| $PWC_{170/kg}$, W/kg | 2.77±0.10 | 3.66±0.19** | 3.12±0.11** | 3.30±0.22** | 3.60±0.16** |

Notes. Reliability of differences in relation to the group of 7–8 years: * – p<0.05, **– p<0.001, p<0.001; in relation to the previous group: ♦– p<0.05, ♠ – p<0.002, ♥ – p<0.001

It is interesting to note the fact of a significant increase in load reverse power (NR, W) at the same physiological price, namely, heart rate of 155 beats/min. A logical explanation for this phenomenon is the positive changes in the structural and functional characteristics of the heart muscle, such as an increase in the size, weight, and volume of the ventricles, an increase in systolic and, accordingly, minute blood volumes, which generally reflects the higher circulatory efficiency of older or trained individuals.

Under these testing conditions, the level of mobilization of extra- and intracardiac functions, the state of regulatory mechanisms and stress of the body of the examined children, adolescents and young people corresponded to the optimal, and adaptive reactions were characterized by adequacy.

## 4. Conclusions

1. The results of the research demonstrate the possibility of building an individual profile and forecasting the functional reserves of children and youth under the conditions of using dosed loads with reverse, in which the degree of reactions of executive and regulatory systems corresponds to the optimal level, and their graphical record takes the form of a hysteresis loop with four informative sections. The correlation between individual elements of the loop and functional capabilities (area, cross-section, angle of inclination, etc.) is established.

2. The increase in physical fitness is followed by the increase in: area of segments of a loop, time of inertia, length of a loop - pulse cost, angle of inclination of a loop upon reduction of load, levels of activation of an organism. There is decrease: loop cross-section, angle of inclination with increasing load, initial, threshold, exit (recovery) heart rate, coefficient of inertia.

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