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PECULIARITIES OF MOBILIZATION AND RECOVERY OF CARDIOVASCULAR SYSTEM IN PERFORMING OF ANAEROBIC LOADS

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ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS FUNKCIJOS MOBILIZACIJOS IR ATSIGAVIMO YPATYBĖS ATLIEKANT ANAEROBINIUS KRŪVIUS

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INTRODUCTION

Lately, attention is more often paid on influence of different types of exercises to interdependence of anaerobic and aerobic processes of metabolism. It is stated that in the course of short-term maximum intensity loads (for instance, a short distance race or other power speed sports events) aerobic processes determine not less than 50% of energy (Spencer et al., 1996). These aerobic processes are controlled by the function of cardiovascular system (Delp, 1998; Spencer et al., 1996; Vainoras, 1996; 2004; Poderys, 2000, Poderys et al., 2005). Thus, cardiovascular system plays one of the most important roles in the constitution of the supplying systems and understanding of the processes taking place in cardiovascular system is significant in estimating adaptation of the body functions to loads while assessing the characteristics of recovery process.

The duration and nature of recovery intervals are two significant components of physical training which determine the inner side of the physical load, the peculiarities of immediate training effect and characteristics of long-term adaptation (Elliott, 1998; Skurvydas, 1999; Poderys, 2000; Bompa, 2001). After exercising physiological functions are normalized unevenly at a different period of time (Astrand, Rodahl, 1970; Gailiūnienė, 1985; Wayne, Westscoth, 1995). Similarly, it is possible to distinguish a heterochronicity in recovery of functional indices in various physiological systems (Astrand, Rodahl, 1970; Shephard, 1987; 2001). Heterochronicity in recovery depends on type of performed loads. Namely, type of the loads determines activation and participation of various body systems during exercising, i.e. the degree of mobilization and the changes of recorded functional indices during recovery process indicate the development of fatigue and individual features of the body (Astrand, Rodahl, 1970; Shephard, 1987; Smith, Norris, 2002; Poderys et al., 2005).

Applying exercise tests usually assesses preparedness and functional state of sportsmen. Measured and maximal exercise tests (*all-out exercise test*) are widely applied (Fletcher et al., 1995; Shephard, 1987; 2001; Smith, Norris, 2002; Maud, Foster, 1995; Poderys et al., 2005). Irrespective on the selected exercise protocol the two main groups of indices are always estimated: the first group – values of recorded indices while performing the exercise test, i.e. estimation of mobilization degree, the second group – the character of changes of indices during recovery after exercising. Recently, the attention is more often paid to complexity of body functions as to the co-operation of its functional elements and synergic interaction (Branger, 1997; Biggiero, 2001; Tulpo et al., 2002; Vainoras, 2004). Likewise, as phenomena excited by the whole differ from single phenomena of certain parts, such synergic interactions are characteristic in activities of the functioning body. Activity of any body functional system possesses many regulating mechanisms (activating and inhibitory) that operate not separately but in the whole synergic interaction. New methods of analysis of research results as well as new methodologies of research broaden the potential of physiologists to explore new, undisclosed characteristics of body functions and to apply them in estimations of functional state in controlling and managing the training process.

Hypothesis. Fast mobilization of body functions as well as speed of recovery process depends on the performed amount and intensity of workouts, type of exercise load and other factors. The recovery

process after physical workouts may have a different recovery sequence of various functional indices; however, sequence in recovery of some important functional indices should be stable, unvarying and independent of function mobilization degree. This sequence in recovery of the cardiovascular indices could be an indicator of the functional state.

Objective of the study was to identify the characteristics of mobilization and recovery of cardiovascular system in performing anaerobic loads.

Tasks of the work:

1. To identify the characteristics of mobilization and recovery of functional indices of cardiovascular system while performing stepwise increasing physical loads up to the inability to continue it.
2. To identify the characteristics of mobilization and recovery of functional indices of cardiovascular system while performing repetitive anaerobic lactatic loads.
3. To identify the characteristics of mobilization and recovery of functional indices of cardiovascular system while performing repetitive anaerobic alactatic loads.
4. To compare the characteristics of mobilization and recovery of functional indices of cardiovascular system while performing all-out vertical jumps tests of 30s and 60s duration of anaerobic load.
5. To estimate the influence of training mezocycle by applying of concentrated anaerobic loads to the recovery characteristics of cardiovascular system

Work novelty and originality.

The mobilization of cardiovascular systems indices while performing anaerobic loads and recovery features after exercise bouts was analysed during these studies. Results obtained during the research were summarized in five extended conclusions and three practical recommendations. The study reveals that a significant feature of recovery after physical loads is an adequate recovery sequence of functional indices of cardiovascular system. Being in normal functional state the relation between regulatory and supplying systems recovers first of all. Later on recover the indices of regulatory systems and latest – indices of supplying systems.

It is pointed out that while performing eight repetitive anaerobic lactatic or anaerobic alactatic exercise bouts many of cardiovascular indices show the summation of effects of repetitive loads, however, mobilization of cardiovascular system does not reach maximum possible limits. In the recovery process after repetitive alactatic loads recovery sequence of cardiovascular indices remains unchanged, however, while performing eight lactatic anaerobic bouts, a tendency of emerges showing that overstepping a certain limit a characteristic feature in sequence of recovery of cardiovascular indices disrupts.

Evaluation of cardiovascular changes during the 60-s all-out vertical jump test (Bosco test) showed that it is a very difficult task and could be used for the assessment of performance abilities only of well-trained athletes. 30-s all-out test in jumping is enough in duration and an accurate estimation of the functional state of cardiovascular system and body functioning during the exercising can be performed.

The influence of concentrated anaerobic heavy training loads used during the training mezocycle on cardiovascular and muscular systems have been estimated. Training loads applied during the mezocycles by using the concentrated and a large amount of exercises designed for development of speed and power abilities should not affect the sequence in recovery of cardiovascular indices and if this sequence is destroyed, so it is a sign that it may be overloaded or some symptoms appear as a result of overtraining of performed hard training program.

1 METHODS AND PROTOCOL OF THE STUDIES

This research was performed in the basis of laboratory of Kinesiology of LAPE (Lithuanian Academy of Physical Education). Local ethical committee approved this study protocol.

1.1 Subjects

Three groups of study participants took part in these studies:

A-group – 25 voluntary students track and field athletes (aged 21,2±0,65, body mass index 22,8±0,34);

B-group – 16 voluntary students who were not engaged in the sport training (aged 20,9±1,21, body mass index 22,3±0,38);

C-group – 17 well-trained athletes (*all participant were members of various national teams*), i.e. endurance group; – sprint group and combative-sport group (*box, judo and wrestling*) (aged 21,8±0,91, body mass index 24,0±0,49).

1.2 Methods

The foolowing methods designed for the assessment of functional state were used:

- Venous occlusion plethysmography
- Reography
- Electrocardiography
- Measuremets of ABP
- Bycicle ergometry
- Roufier exercise test
- Vertical jumps tests
- Model of evaluation of body functioning during exercise

1.3 Protocol of studies:

Firtst study: Peculiarities of mobilization and recovery of cardiovascular indices after graded exercise up to the inability to continue it.

The bicycle ergometric method of incremental increase in workload (graded stress) was used. The subjects underwent a 50W increase in workload every minute (first protocol) or every 6 minutes (second protocol) and they exercised to a predetermined goal (*submaximal heart rate*) unless distressing cardiovascular symptoms supervened. The design of this study is presented in Fig. 1.

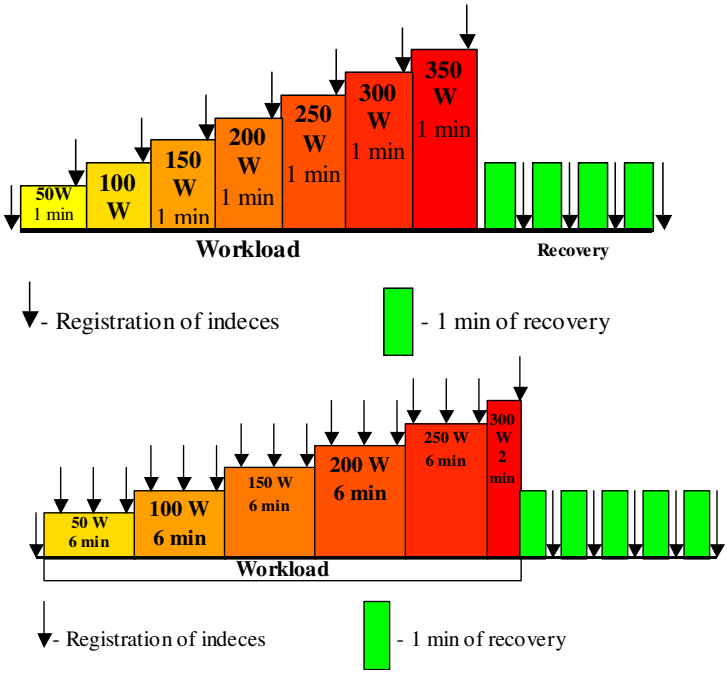


Fig 1. The scheme of registration of cardiovascular indices during the incremental increase in workload (graded stress)

<u>Second and third studies:</u> Peculiarities of mobilization and recovery of cardiovascular indices after repetitive anaerobic lactatic workouts (*second study*) and after anaerobic alactatic workouts (*third study*).

All study participants after warm-up performed 8 repetitive anaerobic workouts. Two and a half of minutes of recovery time was allowed between exercises. The design of this studies is presented in Fig. 2.

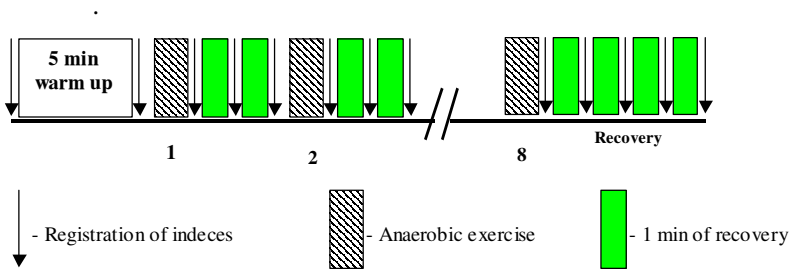


Fig 2. Protocol of organization of the second and third sudies.

<u>Fourth study:</u> Peculiarities of mobilization and recovery of cardiovascular indices after performance of 60-second Bosco repeated jumps anaerobic test and a 30-second all-out repeated jumps test.

Study participants performed a Roufier test, a 60-second Bosco all-out repeated jumps anaerobic test and a 30-seconds all-out repeated jumps test. The jumps were conducted on a force platform. In order

to prevent venous pooling the subjects underwent a 10 s squats after finishing the jumps and sat still during the next 3 minutes of the recovery.

<u>Fifth study:</u> Influence of heavy training loads and peculiarities of recovery of cardiovascular indices

The subject underwent: 1) Roufier test (*30 squats per 45 seconds*); 2) 30-seconds duration maximal vertical jump test. The second investigation was performed after three weeks' of heavy training loads. The design of this study is presented in Fig. 3.

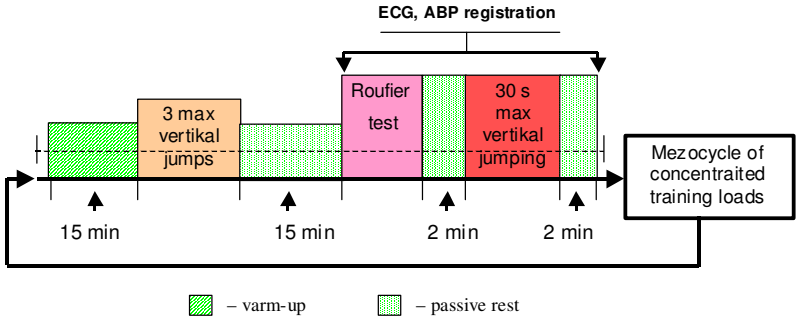


Fig 3. Protocol of organization of the sixt sudy.

1.4. Analysis of results methodology

We used the model of integral evaluation of body functioning during exercise (Vainoras, 1996; 2000; 2004) (Fig. 4) that integrates changes of three functional elements: P – periphery system, R – regulation system (brain), S – supplying system (heart, blood-vessel system). Relation between these systems can be specified by several parameters, but we used the simplest and easiest calculated ECG and ABP parameters: heart rate (HR), JT interval, systolic (S) and diastolic (D) blood pressure. Also we studied proportions between parameters: $\frac{S-D}{S}, \frac{JT}{RR}$, where $RR = 60/HR$. Initial data used in analysis was discrete measurements.

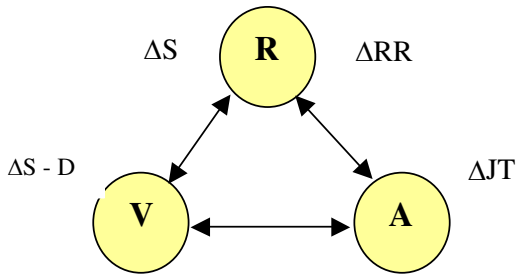


Fig 4. Integrated model for evaluation of body functioning during exercise (Vainoras, 1996)

A computerized ECG analysis system "Kaunas-load", developed by the Institute of Cardiology of Kaunas Medical University, was applied for 12 lead ECG recording and analysis. The changes in RR interval or heart rate (HR), JT interval, ST-segment depression (sum of negative values in 12 leads) and

in the ratio of intervals JT/RR were analyzed. The program also allowed us to evaluate the changes of JT interval – $(JT_i/JT_0)100\%$ in comparison with the changes of RR interval – $(RR_i/RR_0)100\%$ as a difference:

$$V_{adptation} - JT_d = (JT_i/JT_0)100\% - (RR_i/RR_0)100\%.$$

This difference was accepted as velocity of adaptation (V_{Ad}), of cardiovascular system in response to load.

The peculiarities of recovery after workloads was assessed first, by evaluating the time of half period of recovery ($_{1/2}T$) of registered indices and, second, by calculating the recovery value in per cent starting from the change moment which has happened during the load as it was suggested by Lewis and Kingsley (2002):

$$\mathbf{V_{recovery}} = \frac{(\max - recovry)100}{(\max - initial)}$$

*were: **max** – value of indices registered during the load**; recovery** – value of indices registered at the end of first (second) minute of recovery; **initial** – value of indices registered before exercise.*

The third indices in analysis of features in recovery was a Lyapunov exponent (LE_x) that was accepted as an indicator of stability in the whole process of recovery (Suetani et all, 2004), i.e

$LEx = 1/N \Sigma \ln \left| \Delta Xi / Xi \right|$, where Xi – a registered value; ΔXi – a change of the registered value.

2. RESULTS

<u>Firtst study:</u> Peculiarities of mobilization and recovery of cardiovascular indices after graded exercise till the inability to continue it.

The results obtained during the bicycle ergometry of incremental increase in workload showed that there are no differences in the sequence of recovery of ECG indices after the use of both exercise tests. Figure 5 presents the data of recovery after graded exercise tests. These results indicate that after both of exercise tests the sequence in recovery of registered indices was the same. The fastest recovery was of the ratio JT/RR, the second was – heart rate (RR interval), then – JT interval. The same sequence in recovery of indices of arterial blood pressure was observed, i.e. the recovery begins from some ratio between the regulatory and supplying systems of the body, then the recovery in regulatory systems follows and the recovery ends by going down the indices of supplying systems.

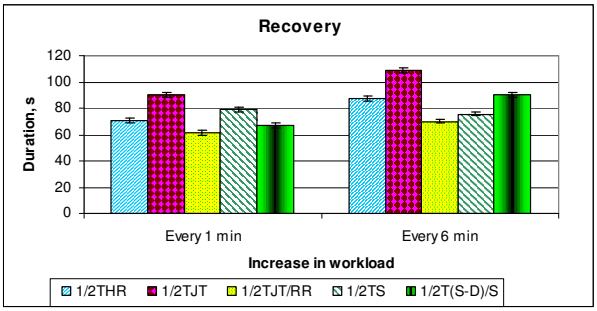
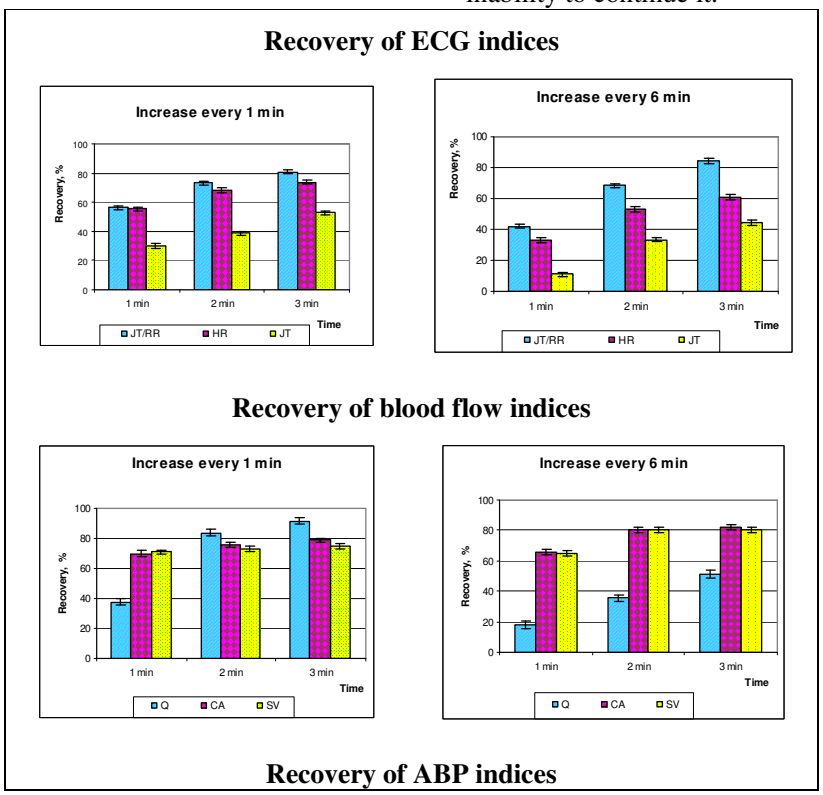


Fig 5. Half time of recovery ($_{1/2}$T) of cardiovascular indices after graded exercise up to the inability to continue it.



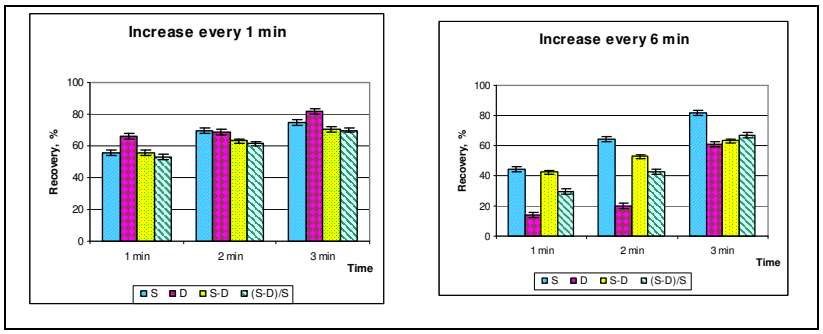


Fig.6. Recovery of cardiovascular indices after graded exercise till the inability to continue it at the various times after workload.

The obtained results during this study can be summarized as follows:

- ✓ While performing incremental exercise load until inability to continue it, the greatest changes are recorded in JT interval of ECG and in ratio of intervals JT/RR.
- ✓ A characteristic feature of recovery after physical loads is an adequate sequence in recovery of cardiovascular system indices.
- ✓ In the process of recovery proportion of JT/RR recovers the most quickly, then RR, and the latest follow it – by JT interval.
- ✓ The duration of semi-periods of recovery of relative arterial blood pulse pressure and systolic ABP are pointedly longer than semi-periods of recovery of ECG indices.

<u>Second and third studies:</u> Peculiarities of mobilization and recovery of cardiovascular indices after repetitive anaerobic lactatic workouts (*second study*) and after anaerobic alactatic workouts (*third study*).

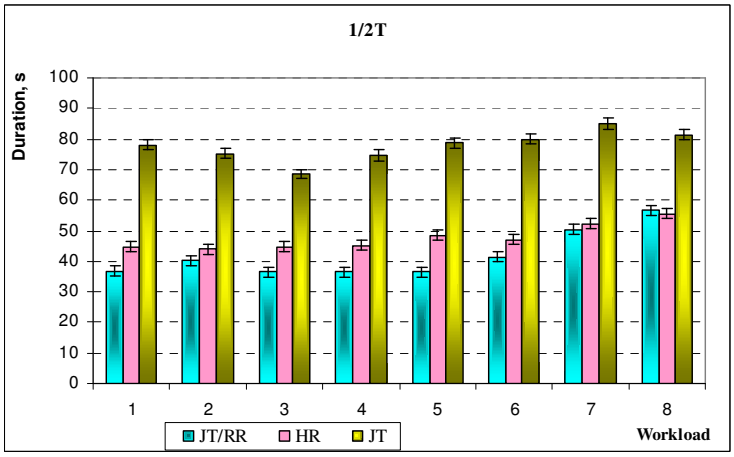


Fig.7. Half time of recovery ($_{1/2}$T) of ECG indices after repetitive anaerobic lactatic workouts (*second study*)

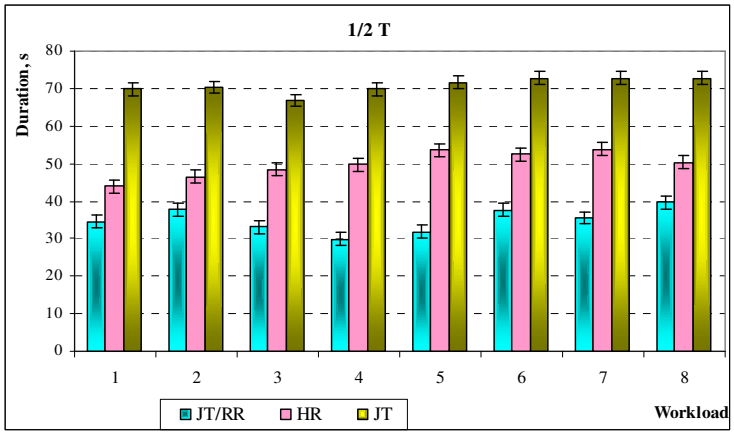
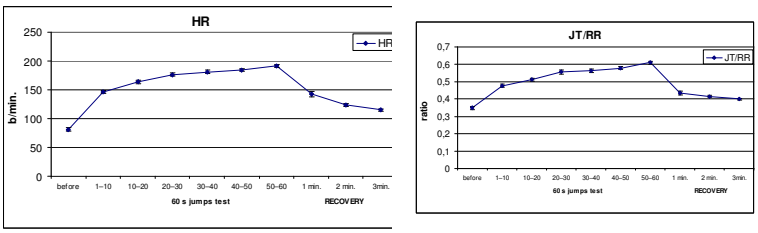


Fig.8. Half time of recovery ($_{1/2}$T) of ECG indices after repetitive anaerobic alactatic workouts (*third study*)

<u>Fourth study:</u> Peculiarities of mobilization and recovery of cardiovascular indices after performance of 60-second Bosco repeated jumps anaerobic test and a 30-second all-out repeated jumps test.

At onset of repeated jump test a steep increase of cardiovascular indices occurred. Figure 9 presents the dynamics of registered ECG indices when performing a Bosco 60 s repeated jump test and during the recovery. Some of the indices, such as heart rate, JT interval and JT/RR ratio increased rapidly and at the end of exercise test they increased up to the maximum values. The values of changes depended on the duration of the workload but no significant differences in dynamics of cardiovascular indices during the first 30 s of jumping were found. If to compare the maximal values registered at the end of used both jumps tests the greatest changes during the performance of 60-s Bosco repeated jumps test were obtained. The statistically significant differences were between the changes in heart rate, JT interval, ST-segment depression, ratio of JT/RR and systolic ABP ($p<0,05$).

The results obtained during this study have shown that the ratio JT/RR can be useful for outlining to what extent a cardiovascular function was mobilized. The mobilization of cardiovascular function when performing a Roufier test has changed up to 0,427±0,008, when performing a 30-s jump test – up to 0,454±0,012 and when performing a Bosco test as it was shown in figure 1 up to the maximal values, i.e. 0,634±0,004.



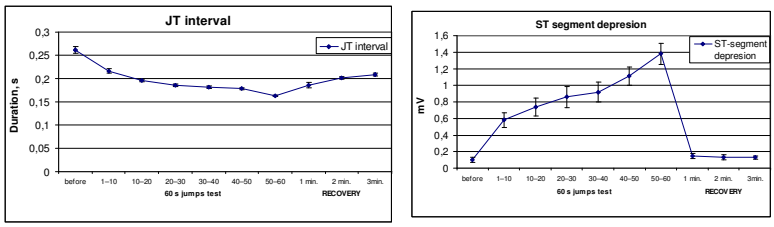


Fig. 9. Dynamics of ECG indices when performing a Bosco 60 s repeated jump test and during the recovery

Table 1. Velocity of adaptation (V_{Ad}) and half recovery time ($_{1/2}T$) of cardiovascular indices

Exercise Test	V_{Ad}	$_{1/2}T$ HR	$_{1/2}T$ JT	$_{1/2}T$ JT/RR	$_{1/2}T$ (S-D)/S
Roufier Test	19,2±1,4	28,1±1,7	48,1±1,8	25,3±1,8	60,6±3,2
30-s jump Test	20,3±2,0	61,7±3,6	81,6±3,5	40,1±2,1	87,8±3,4
Bosco Test (60-s jump)	20,6±2,8	82,1±4,1	96,2±4,2	52,5±2,3	110,3±3,9

Table 2. Peculiarities of recovery of cardiovascular indices after exercise tests *(values of Liapunov exponent – LE)*

Exercise Test	LEHR	LE_{JT}	$LE_{JT/RR}$	$LE_{(S-D)/S}$
Roufier Test	- 0,15±0,04	- 0,09±0,04	- 0,19±0,04	- 0,06±0,03
30-s jump Test	- 0,28±0,06	- 0,25±0,03	0,11±0,07	- 0,02±0,03
Bosco Test (60-s jump)	0,12±0,05	- 0,02±0,05	0,13±0,06	0,02±0,03

The slowest recovery of cardiovascular indices was observed after the Bosco test (60-s all-out anaerobic test). The analysis of correlations of figures obtained in half period of recovery time after 30-s duration and 60-s duration of repeated jump tests has shown the following values of correlation, i.e. $_{1/2}T_{HR}$ r = 0,68; $_{1/2}T_{JT}$ r = 0,71; $_{1/2}T_{JT/RR}$ r = 0,65 and $_{1/2}T_{(S-D)/S}$ r = 0,42. All these correlations were statistically significant and indicate about similarities between the two jumps tests concerning the assessment of individual peculiarities of recovery.

Table 2 presents the figures of Liapunov exponent (LEx) obtained in the process of analysis of the dynamics of indices registered during the recovery. Statistically significant differences between the

values of LEx_{HR} obtained after Roufier test and 60s repeated jump test ($p<0,05$), between the values of LE_{HR} obtained after 30s and 60s repeated jump tests ($p<0,05$), as well as between values of $LEx_{JT/RR}$ obtained after Roufier test and 60s repeated jump test ($p<0,05$) were found. It is rather difficult to account for these data but the main criterion in assessment of the stability of the process involved is a positive or negative sign of LEx. The negative sign indicate the stability in the process, i.e. in the dynamics of the indices during the recovery and the positive sign indicates instability that can be due to some discoordination of the correspondent mechanisms. The tinted panes in table 3 mark the cases where the LE is positive and it indicates that 60-s duration of all-out jump test has a negative influence on the stability of the recovery processes of cardiovascular indices.

Fifth study: Influence of heavy training loads and peculiarities of recovery of cardiovascular indices

These results indicate that after exercise tests the sequence in recovery of registered indices was the same as we observed during the previous studies. The faster recovery was of the ratio JT/RR, after then recovery of heart rate (RR interval), then – of JT interval. The same sequence in recovery of indices of arterial blood pressure was observed, i.e. the recovery begins from some ratio between the regulatory and supplying systems of the body, then the recovery in regulatory systems follows and the recovery ends by going down the indices of supplying systems. The results obtained during the assessment peculiarities of recovery after heavy training loads have shown some only changes. There was no statistically significant difference between obtained averages ($p>0.05$). The sequence in recovery of registered cardiovascular indices was the same. But, if to take into account the individual variations the sequence in recovery was destroyed in some cases, which coincident with the changes in the stability of recovery process about which the Lyapunov exponent (LEx) has indicated. Individual data analysis showed that the cases when the sequence in recovery of cardiovascular indices was destroyed one or a few of LEx indices have changed to a positive mark. The cases where the LEx was positive and it indicates that the 3 weeks of heavy training loads has made a negative influence on the stability of the recovery processes of cardiovascular indices coincided with the decrease in muscle power during the jumps task.

3. GENERALIZATION OF RESULTS

The problem of evaluating the mobilization of the body functioning during exercise combines two aspects or questions: first, the velocity of adaptation at onset of exercise, and second, to what extent the body function was mobilised.

There are not so many methods designed for the assessment of individual peculiarities of mobilization of the body functioning during the exercising. Energy system approach is fit enough for explanation of matters but it is difficult to use in practice. On the other hand given repeated reproduction over the years, these early attempts have lead to 2 common misconceptions in the exercise science and coaching professions (Gastin, 2001). First, that the energy systems respond to the demands of intense exercise in an almost sequential manner, and secondly, that the aerobic system responds slowly to these energy demands, thereby playing little role in determining performance over short durations. More recent research suggests that energy is derived from each of the energy-producing pathways during almost all exercise activities. The duration of all-out exercise at which equal contribution is derived from the anaerobic and aerobic energy systems occurs considerably earlier than has been traditionally suggested. (Green, 1995, Spencer el all., 1996; Gastin, 2001). We must point out that the last year studies have shown a great importance of complexity in body functioning (Bigero , 2001; Tulpo et all, 2002). Since the cardiovascular system is one of the constituent part and a holistic system of the body therefore the reactions of cardiovascular system to constant-load tests or all-out tests allows one to assess the functional capabilities and functional peculiarities of the body (Perkiomaki, 2003). The results obtained in this study have shown what a significant role in developing and improving the velocity of adaptation of cardiovascular system at onset of exercise is played by the exercise type or type of adaptation. (Poderys, 2000).

When assessing individual peculiarities of the body functioning during the workloads it is important to evaluate at what extent the body function was mobilised during the performance of the task. Absolute values such as heart rate during exercising can be used for these purposes. Such methods are practical but not precise for outlining to what extent the mobilisation of cardiovascular system occurred (Perkiomaki, 2003, Poderys, 2004). Comparisons of results of all researches made by us during these studies showed that one of the most appropriate indices to assess mobilization features of cardiovascular system is the change of JT/RR interval proportion of ECG. The results of our studies revealed that maximum mobilization degree of cardiovascular system was reached by performing graded exercises till the inability to continue it (in both researches – every minute, and also every six minutes while increasing load), as well as carrying out Bosco test. In other cases when jumping test lasted 30 seconds, after Rufje test, while performing repetitive lactatic, repetitive alactatic loads, the change of JT/RR proportion pointed out that maximum mobilization of cardiovascular system had not been achieved. It means that while performing tests of non-maximum loads and repetitive loads the ratio JT/RR can be used as the indicator of mobilization degree.

A special study performed by Boshkov (Бочков) in 1986, has shown that activation of physiological systems could be expressed by normalised values in ratio of underlying indices of the

physiological system, that are mathematically expressed as follows: 1/e=0,368 and 1-1/e =0,63, where e – a base of a natural logarithm. In this way the degree of system mobilization can be estimated in case the selected indicator is the underlying indicator of the functional system. In the same research Bochkov (1986) pointed out that one of the most substantial variables of cardiac functions is a normalized proportion of a systole and the whole cycle durations. These underlying indices of cardiac function can be the ratio of JT and RR intervals (Vainoras, 1996). The JT interval is not dependent of the ventricular repolarisation pattern and can be used as an accurate means of following the duration of ventricular repolarisation (Banker, 1997; Hlaing, 2005) and its changes interrelate with the changes in the intensity of cardiac metabolism (Vainoras, 2002). Interval RR of ECG – cardiac cycle duration indicator, JT interval is closely coincident with the heart systole duration.

The results obtained during this study have shown that the ratio of JT/RR can be useful for outlining at what extent a cardiovascular function was mobilised. As it was found during the incremental increase in workload (till the inability to continue the task) the ratio in JT/RR has varied very closely or even coincided as it was established by Boshkov in 1986. When performing dosed workloads (*Roufier test – aerobic workout*) and during 30-second all-out test in jumping (*anaerobic workout*) the changes in ratio JT/RR were in dependence on the performance abilities (*training experience*) and functional state. The ratio of JT and RR intervals (JT/RR) of ECG provides the information concerning the dynamics of mobilization of cardiovascular system during the workouts.

To sum up, we may say that the above cited studies of others scientists and results obtained during this research manifested the significance of relative indices in estimating mobilization of cardiovascular function while performing various physical loads.

Anaerobic tests are designed to measure anaerobic power and anaerobic capacity (Green, 1995). The development of simple, non-invasive tests of work capacities, underpinned primarily by anaerobic metabolism, proliferated in the early 1970s. A 30-second maximal cycle test developed at the Wingate Institute initiated efforts to develop work tests of anaerobic capacities. Various tests, such as force-velocity tests, vertical jump tests, staircase tests, and cycle ergometer tests are used. The first studies concluded that the values of maximal anaerobic power and anaerobic capacity obtained with these different protocols are different but generally well correlated (Vanderwale at al., 1989). But the last studies have shown that each test, for example the Bosco and Wingate tests, both of which measure anaerobic characteristics, appear to measure different aspects of anaerobic power and capacity. The Bosco test also may be inappropriate for individuals who are not well trained in jumping (Sands et al., 2004). The results of our study showed that the steep increase of ST-segment depression was observed at onset of jumping and mostly at the last 20 s of jumping that indicates functional ischemic episodes in cardiac musculature. Prognostic importance of ischemic episodes detected by ST-segment monitoring with continuous 12–lead ECG during exercise test has been shown in many investigations (Jernberg, 1999; Yazigi et al., 1998 Vainoras, 1996, 2002). The ST-segment depression at the end of the Bosco test indicates transient, functional ischemical processes in cardiac muscle that could be taken as heart function limiting failure during the load. Results obtained during the study showed tat 60-s of all-out jump test has made a negative influence on the stability of the recovery processes of cardiovascular indices. Decrease in

complexity of functioning of cardiovascular system of non-athletes after 60-s all-out jumps are the most evident in relational values of ECG as JT/RR and ABP such as relative pulse pressure (S-D)/S. The 60-s all-out vertical jump test (Bosco test) is very difficult task and could be used for the assessment of performance abilities only of well-trained athletes. 30-s all-out test in jumping is enough in duration and an accurate estimation of the functional state of cardiovascular system and body functioning during the exercising can be performed.

Gradual recovery of functional indices was observed in the process of recovery (*return to primary level*). In this study we assessed the recovery of ECG and some important indices of circulatory system. The obtained results of the research revealed some important characteristics. According to the results of assessments of ECG indices and how these results look on the model of evaluation of body functioning during exercising. Sequence in recovery of cardiovascular indices is important feature of recovery after exercising. First of all the proportion between regulation and supply systems is recovered after the exercise bout (the quickest is recovery of JR/RR), later regulation system indices recover (RR interval) and the latest – indicator of supplying systems (JT interval). That happened in every case during ours studies, i.e. as after performance graded exercise stress of gradually increasing physical loads irrespective of the duration of load level, as after vertical jumps tests of 30s and 60s, as after Roufier test, as after of each exercise bout when eight repetitive anaerobic workouts was performed. Hence, a certain sequence in recovery of indices is a significant indicator.

If to come back to hypothesis of the research that the sequence of certain underlying functional indices of cardiovascular system should be stable and unvarying and sequence in recovery of these indices could be one of the indices of functional state, we can maintain that our hypothesis proved out. The recovery sequence of ECG indices – JT interval, RR interval and ratio of ECG intervals JT/RR was the same after incremental increase in workloads applied by us as well as after repetitive anaerobic alactatic and repetitive lactatic exercise loads, also after Roufier test, 30s vertical jumps test, 60s vertical jumps Bosco test. Recovery sequence of these indices also remained unchanged after mesocycle of concentrated and heavy training anaerobic loads. Only in the cases when muscle power abilities of the subjects decreased and the other cardiovascular indices showed the worsening of functional state of the subjects, it was related to the changed recovery sequence of these significant ECG indices. Therefore, recovery sequence of ECG indices could be the functional state indices while estimating physical state of sportsmen and managing the process of a training process.

We must admit that both types of assessments of recovery used by us, i.e. semi-period of recovery ($_{1/2}$ *T- time during which the indicator recovers till the half of the accomplished change*) and recovery value calculated according to the formula suggested by English scientists (Lewis, Kingsley, 2002) expressed in per cent (*how many per cent indices recovered during a chosen period of time*), are equivalent in the meaning of informativeness, therefore, only the possibility of a researcher to take advantage of the computer software while collecting research data should determine which of the indices is applicable.

CONCLUSIONS

1. A characteristic feature of recovery after physical loads is an adequate sequence in recovery of cardiovascular system indices. The indices outlining features in ratio between regulatory and supplying systems recovers firstly, after than the recovery of regulatory systems occurs and the slowest recovery is of the indices of supplying systems.
    - ✓ *While performing incremental exercise load up to inability to continue it, the greatest changes are recorded in JT interval of ECG and in ratio of intervals JT/RR.*
    - ✓ *In the process of recovery JT/RR proportion recovers the most quickly, then it is followed by RR, and the latest – by JT interval.*
    - ✓ *The duration of semi-periods of recovery of relative arterial blood pulse pressure and systolic ABP are pointedly longer than semi-periods of recovery of ECG indices.*
2. While performing eight repetitive anaerobic lactatic workouts many of cardiovascular indices shows the summation of fatigue as an effect of repeated bouts, however, mobilization of cardiovascular indices does not attain maximum of possible limits. In the recovery process after repetitive loads the sequence of recovery of cardiovascular indices remains unchanged till the sixth repetition. There is a tendency that after overstepping a certain limit the characteristic feature in sequence of recovery of cardiovascular indices disrupts.
3. While performing eight repetitive anaerobic alactatic workouts many of cardiovascular indices show the summation of fatigue as an effect of repeated loads and mobilization of cardiovascular indices do not attain maximum of possible limits. In the recovery process after each of repeated load the sequence of recovery of ECG and ABP indices remain unchanged.
4. The 60-s all-out vertical jump test (Bosco test) is a very difficult task and could be used for the assessment of performance abilities only of well-trained athletes. 30-s all-out test in jumping is enough in duration and an accurate estimation of the functional state of cardiovascular system and body functioning during the exercising can be performed.
5. Training loads applied to during the mezocycles by using the concentrated and a large amount exercises designed for the development of speed and power abilities should not affect the sequence in recovery of cardiovascular indices and if this sequence is destroyed it could be estimated as a sign of overtraining.

RECOMMENDATIONS

1. The 60-s all-out vertical jump test (Bosco test) is recommended solely for estimation of changes in anaerobic working capacity of well trained person. For the assessments of untrained person abilities a shorter in duration jump tests should be applied.
2. It is advisable to assess the sequence in recovery of cardiovascular indices for a more precise estimation of influence of concentrated exercise loads on the peculiarities of body functioning. The cases of destroying this sequence must be assessed as a sign of indicating the overloads or some other symptoms of overtraining.
3. The methodology while calculating the percentage recovery value starting from the moment of change that appeared during the load is recommended for the assessment of recovery after exercising.

PUBLICATIONS

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SANTRAUKA

Pastaruoju metu vis dažniau atkreipiamas dėmesys į nevienareikšmį įvairaus kryptingumo fizinių krūvių poveikį anaerobinių ir aerobinių medžiagų apykaitos procesų tarpusavio sąsajoms. Daugel metų deklaruotas energijos gavybos būdų aktyvavimo nuoseklumas, atliekant fizinius krūvius, tarp fiziologų, trenerių sporto specialistų suformavo dvi klaidingas nuomones (*angl.– common misconceptions,* Green, 1995). Visų pirma, kad energinės sistemos aktyvuojamos paeiliui, ir antra, kad aerobinis energijos gavybos būdas yra inertiškas, dėl to teturi mažą poveikį mažesnės trukmės intensyvių fizinių krūvių metu. Mokslininkai (Green, 1995; Spencer et al., 1996; Gastin, 2001) parodė, kad energija raumenų darbui atlikti beveik visuomet yra gaunama iš visų trijų energinių sistemų ir kad, atliekant fizinius krūvius didžiausiomis pastangomis, perėjimas, t. y. riba, kai energijos gavyba tiek anaerobiniu, tiek aerobiniu būdu tampa lygiavertė, įvyksta daug greičiau nei buvo teigiama vadovėliuose.

Sportuojančių asmenų parengtumą ir funkcinę būklę priimta vertinti taikant fizinio krūvio testus. Plačiai yra taikomi dozuoto ar maksimalaus krūvio testai (Shephard, 1987; 2001; Fletcher ir kt., 2001; Smith, Norris, 2002; Maud, Foster, 1995; Poderys ir kt., 2005). Nepriklausomai nuo pasirinkto fizinio krūvio protokolo yra vertinamos dvi pagrindinės grupės rodiklių: pirma – registruojamų rodiklių reikšmės atliekant fizinio krūvio testą, t. y. mobilizacijos laipsnio vertinimas, ir antra – rodiklių kaita atsigavimo metu. Pastaruoju metu vis dažniau atkreipiamas dėmesys į organizmo kompleksiškumą, kaip jo funkcinių elementų kooperaciją, sinerginę sąveiką (Branger, 1997; Biggiero, 2001; Tulpo ir kt., 2002; Vainoras, 2004). Lygiai taip pat, kaip visumos sužadinti reiškiniai skiriasi nuo tam tikrų dalių pavienių reiškinių, tokios pat sinerginės sąveikos būdingos žmogaus organizmo veiklai. Bet kurios organizmo funkcinės sistemos veikloje yra daug reguliuojamųjų mechanizmų (aktyvinamųjų ir slopinamųjų), kurie veikia ne atskirai kiekvienas sau, o bendroje sinerginėje sąveikoje. Nauji tyrimo rezultatų analizės metodai, nauja tyrimo metodologija išplečia fiziologų galimybes pažinti organizmo funkcijos naujas, lig šiol neatskleistas ypatybes, panaudoti jas vertinant funkcinę būklę, kontroliuojant ir valdant sporto treniruotės procesą.

Darbo hipotezė. Organizmo funkcijų mobilizacijos, o kartu ir atsigavimo procesų sparta priklauso nuo atlikto krūvio dydžio, jo pobūdžio ir kitų veiksnių. Atsigavimo po fizinių krūvių procese galima įvairi funkcinių rodiklių atsigavimo seka, tačiau kai kurių esminių funkcinių rodiklių atsigavimo seka turėtų būti stabili, nekintama ir nepriklausyti nuo funkcijos mobilizacijos laipsnio. Atsigavimo seka galėtų būti vienas iš funkcinės būklės rodiklių.

Darbo tikslas – nustatyti ŠKS mobilizacijos ir atsigavimo ypatybes atliekant anaerobinius krūvius.

Darbo uždaviniai:

1. Nustatyti ŠKS funkcinių rodiklių mobilizacijos ir atsigavimo ypatybes atliekant pakopomis didėjančius fizinius krūvius iki negalėjimo.
2. Nustatyti ŠKS funkcinių rodiklių mobilizacijos ir atsigavimo ypatybes atliekant kartotinius anaerobinius laktatinius krūvius.
3. Nustatyti ŠKS funkcinių rodiklių mobilizacijos ir atsigavimo ypatybes atliekant kartotinius anaerobinius alaktatinius krūvius.

4. Palyginti ŠKS funkcinių rodiklių mobilizacijos ir atsigavimo ypatybes atliekant 30 ir 60 s trukmės anaerobinio krūvio vertikalių šuolių testus.
5. Įvertinti koncentruotų anaerobinių krūvių mezociklo poveikį ŠKS funkcinių rodiklių atsigavimo ypatybėms.

Darbo originalumas.

Šiame darbe išnagrinėtos širdies ir kraujagyslių sistemos mobilizacijos ir atsigavimo proceso ypatybės atliekant anaerobinius krūvius. Parodyta, kad reikšminga atsigavimo po fizinių krūvių ypatybė yra atitinkama širdies ir kraujagyslių sistemos funkcinių rodiklių atsigavimo seka. Esant normaliai funkcinei būklei pirmiausia atkuriamas reguliavimo ir aprūpinančiųjų sistemų santykis, paskui atsigauna reguliuojamųjų ir vėliausiai – aprūpinančiųjų sistemų rodikliai. Parodyta, kad atliekant kartotinius anaerobinius laktatinius ir anaerobinius alaktatinius krūvius daugelis ŠKS rodiklių rodo kartojamų krūvių sumos efektą, tačiau ŠKS mobilizacija nepasiekia didžiausiųjų galimų ribų. Atsigavimo procese po kartojamų alaktatinių krūvių ŠKS rodiklių atsigavimo seka lieka nepakitusi, o atliekant laktatinius krūvius yra polinkis, kad peržengus tam tikrą ribą būdinga atsigavimo procesų seka pradeda išsiderinti. Įvertintas koncentruotų anaerobinių fizinių krūvių mezociklo poveikis ŠKS atsigavimo ypatybėms. Įvertintos ŠKS funkcijos ypatybės atliekant įvairios trukmės šuoliavimo (anaerobinius testus). Parodyta, kad minutinis šuolių testas yra labai sunkus fizinio krūvio mėginys ir todėl gali būti taikomas tik gerai treniruotų asmenų parengtumui vertinti. Per 50 s šuolių ŠKS mobilizacija jau pasiekia maksimalias ribas.

Išvados:

1. Reikšminga atsigavimo po fizinių krūvių ypatybė yra atitinkamas širdies ir kraujagyslių sistemos funkcinių rodiklių atsigavimo nuoseklumas. Esant normaliai funkcinei būklei pirmiausia atgaunamas reguliuojamųjų ir aprūpinamųjų sistemų santykis, tada atsigauna reguliuojamųjų ir vėliausiai – aprūpinamųjų sistemų rodikliai.
    - *atliekant pakopomis didėjančius fizinius krūvius iki negalėjimo, įvyksta didžiausi elektrokardiogramos JT intervalo bei JT/RR santykio pokyčiai,*
    - *atsigavimo metu visuomet greičiausiai atsigauna JT/RR santykis, paskui – RR, vėliausiai JT intervalas.*
    - *Elektrokardiogramos JT intervalo ir AKS santykinės pulsinės amplitudės: (S-D)/S atsigavimo pusperiodžiai yra reikšmingai ilgesni nei ŠSD ir santykio JT/RR atsigavimo pusperiodžiai.*
2. Atliekant aštuonis kartotinius anaerobinius laktatinius krūvius daugelis ŠKS rodiklių rodo kartojamų krūvių sumos efektą, tačiau ŠKS mobilizacija nepasiekia didžiausiųjų galimų ribų. Atsigavimo metu atlikus kartojamus krūvius rodiklių atsigavimo seka lieka nepakitusi iki šešto kartojimo ir yra polinkis, kad peržengus tam tikrą ribą būdinga atsigavimo procesų seka pradeda išsiderinti.
3. Atliekant aštuonis kartotinius anaerobinius alaktatinius krūvius ŠKS rodiklių rodo kartojamų krūvių sumos efektą, tačiau ŠKS mobilizacija nepasiekia didžiausiųjų galimų ribų. Atlikus kartojamus krūvius atsigavimo metu EKG ir AKS rodiklių atsigavimo seka išlieka nepakitusi.

4. Minutinis šuolių testas yra labai sunkus fizinio krūvio mėginys ir todėl gali būti taikomas tik gerai treniruotų asmenų parengtumui vertinti. Per 50 s šuolių ŠKS mobilizacija pasiekia didžiausiąją ribą. Vertinant individualias tiriamųjų ŠKS funkcijos mobilizacijos ypatybes tinkamesni trumpesni testai.
5. Koncentruoti didelės apimties jėgos greitumo fiziniai krūviai, taikomi per mezociklo pratybas, neturi paveikti rodiklių atsigavimo eiliškumo, o atvejai, kai atsigavimo procesų eiliškumas kinta turi būti vertinami kaip per didelių krūvių efektas.

Praktinės rekomendacijos:

1. Bosco vertikalių šuolių testas rekomenduotinas tik gerai treniruotų asmenų anaerobinio darbo talpos pokyčiams vertinti, o atliekant netreniruotų asmenų tyrimus turi būti taikomi trumpesni testai. Individualių tiriamųjų ŠKS funkcijos mobilizacijos ypatybėms vertinti turi būti parenkami trumpesnės trukmės nei 60 s Bosco testas.
2. Vertinant didelės apimties koncentruotų jėgos greitumo fizinių krūvių poveikį sportininko organizmui, tikslinga vertinti EKG rodiklių atsigavimo eiliškumą, o atvejai, kai įvyksta EKG rodiklių atsigavimo eiliškumo kaita, turi būti vertinami kaip per didelių krūvių ar neadekvačių fizinių krūvių efektas.
3. Atsigavimo po fizinių krūvių eigai vertinti rekomenduotina metodika, skaičiuojant atsigavimo dydį procentais nuo krūvio metu įvykusio pokyčio.

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