Mobilization of cardiovascular function during the constant-load and all-out exercise tests

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Key words: cardiovascular system, ECG analysis, exercise tests.

Summary. The problem of evaluating the mobilization of body functioning during exercise combines two questions: first, the velocity of adaptation at onset of exercise, and second, to what extent the body function was mobilized. The aim of this study was to find out the peculiarities in mobilization of cardiovascular function during constant-load and all-out exercise tests in non-athletes and sportsmen: cohorts of sprinters, endurance and combat athletes. Every subject underwent a Rouvier’s test (30 squats per 45 seconds), a 30-second duration maximal vertical jump test, and a bicycle ergometry (graded stress). Indirect arterial blood pressure measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff and various indices registered in 12-lead electrocardiogram (ECG) using a computerized ECG analysis system “Kaunas-load” were analyzed. The results obtained during the study showed that the change in ratio of JR/RR intervals of ECG allows assessing the dynamics of mobilization of cardiovascular system during the exercise tests or workouts. The greater mobilization of cardiovascular system when performing constant-load exercise tests is rather characteristic for non-athletes than sportsmen’s cohorts. Constant-load exercise tests rather than all-out exercise tests are more suitable for assessments of individual peculiarities or differences between the cohorts. The individual peculiarities in velocity of adaptation of cardiovascular system at onset of exercise can be evaluated making use of the index of velocity of adaptation (V_ad), which represents the difference between the relative changes of JT and RR intervals of ECG. Velocity of adaptation at onset of exercise depends on the residual effects of training but not on the type of exercise test.

Introduction
At the onset of exercise a cardiovascular system adapts to the variations of loads with a series of integrated response to meet the metabolic demands of the exercising muscles (1). Consequently, a number of indices exist for the measurement of response of body functions to exercise bouts. In practice, the response to exercise can be evaluated by measuring the changes in the performance of one or another system (1–4). Recently, more frequent research has been carried out to examine the response of body to exercise as an integral impact on the body (5–7). The cardiovascular system is one of holistic system of the human body and the reactions of cardiovascular system to constant-load test or all-out test reveal the peculiarities of body functioning (8).

Velocity of adaptation of body functions to physical loads is an important feature from a health perspective and, on the other hand, a fast mobilization of body functions at onset of exercise is important in many kinds of sport and there are a lot of situations in competitive sport when this ability is a decisive factor and important feature of functional capabilities. The aim of this study was to determine the peculiarities in mobilization of cardiovascular function during constant load and all-out exercise tests in non-athletes and sportsmen’s cohorts.

Material and methods
The study participants were 17 voluntary students non-athletes (mean age 20.9±1.21, body mass index 22.3±0.38) and 63 well-trained athletes (all participants were members of various national teams), i.e. group of 23 endurance athletes, group of 19 sprinters and group of 21 combat sports (box, judo and wrestling) athletes.

Local ethical committee approved this study protocol. Every subject underwent: 1) a Rouvier’s test (30 squats per 45 seconds); 2) a 30-second duration maximal vertical jump test, 3) a bicycle ergometry of incremental increase in provocative workload (graded stress). During the bicycle ergometry the subjects
underwent a 50 W increase in workload every 60 seconds (60 revolutions/min) and they exercised to a predetermined goal (submaximal heart rate) unless distressing cardiovascular symptoms supervened.

Indirect arterial blood pressure (ABP) measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff before, after exercise test during the first minutes of the recovery. A computerized electrocardiogram (ECG) analysis system “Kaunas-load”, developed at the Institute of Cardiology of Kaunas University of Medicine, was employed for synchronous 12-lead ECG recording and analysis. The changes in RR interval or heart rate (HR), JT interval, ST-segment depression as a sum in 12 leads and the ratio of intervals JT/RR were analyzed. A computerized program allowed to evaluate the velocity of adaptation of cardiovascular system to exercise, i.e. the index of velocity of adaptation (V_ad), by calculation the difference between the relative changes of JT interval and RR interval:

\[ V_{ad} = \frac{(JT_1/JT_0) \times 100\% - (RR_1/RR_0) \times 100\%}{100\%} \]

The significance of the difference between parametrical and nonparametric values was evaluated by computing t-criterion. The difference has been considered statistically significant, when \( p \) was <0.05 (95% confidence intervals).

**Results**

Table 1 presents the values of cardiovascular indices in cohort of non-athletes before exercise and their maximal values obtained during the various exercise tests. Two of used exercise tests were difficult to continue the performance of the workout during the last seconds, i.e. the bicycle ergometry of incremental increase in workload and the 30-second repeated jumps anaerobic test. The figures presented in Table 1 indicate that the mobilization of cardiovascular function was the highest during the performance of these two tests. The results obtained during the bicycle ergometry of incremental increase in provocative workload showed that the greatest ability to perform the incremental workload was in the endurance group (data not shown). All participants of experiment underwent a workload of 300 W and 60% of them even 350W. Representatives of non-athletes group have showed the least working capacity. They were able to reach the workload up to 200–250 W. A significant difference between sprint and duelist sports groups was not found (\( p > 0.05 \)). The participants of these cohorts underwent a workload of 250–300 W. There were no statistically significant differences in heart rate, arterial blood pressure values and JT/RR values between the groups (\( p > 0.05 \)) at the end of workout of incremental increase in workload. This is an evidence that a full mobilization of functional abilities of the body in all cohorts was reached. The differences between cohorts were manifested in values of ST-segment depression at the end of workout, in values of changes of cardiovascular indices at the same grades of the task, in relative changes of cardiovascular indices with the performance, i.e. a developed power on bicycle ergometer.

The results presented in Table 2 demonstrate that the velocity of adaptation at onset of exercise depends on the residual effects of training but not on the type of exercise-test. The significant differences between values in velocity of adaptation in response to exercising were not found when three various test protocols were used (Roufier’s test, 30-second duration maximal vertical jump test, or incremental increase in workload). The fastest adaptation at onset of exercise was in sprint group (16.3±1.33%). The values of velocity of adaptation in endurance group were 19.8±1.34%. The difference between sprint and endurance cohorts was statistically significant (\( p < 0.05 \)). The velocity of adaptation in group of non-sportsmen was the slowest – 21.4±1.33%. Summarizing, the faster adaptation at onset of exercise is quite characteristic for sprint and duelist than endurance or non-sportsman cohorts.

Figure presents the comparison of the mobilization of cardiovascular function during the various exercise tests. There were no differences in the ratio of JT interval and RR interval (JT/RR) between cohorts at the end of graded stress, i.e. when maximal mobilization of muscular and cardiovascular systems was obtained. On the other hand, the greatest difference between cohorts was revealed at 30-second duration of all-out maximal vertical jump test. The greatest values were in the group of non-sportsmen and the least in endurance group. The difference between these cohorts was statistically significant (\( p < 0.05 \)). The Roufier’s test also revealed the differences between the cohorts.

**Discussion**

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 mobilized.

There are not so many integral methods designed for the assessment of individual peculiarities of mobi-
Table 1. Cardiovascular indices registered before (upper row) and at the end of exercise tests workout (lower row) in cohort of non-athletes

<table>
<thead>
<tr>
<th>Indices</th>
<th>Exercise test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roufier’s test</td>
</tr>
<tr>
<td>HR, b/min</td>
<td>80.0±3.71</td>
</tr>
<tr>
<td></td>
<td>124.6±4.23</td>
</tr>
<tr>
<td>JT interval, ms</td>
<td>260±9.43</td>
</tr>
<tr>
<td></td>
<td>208.9±5.39</td>
</tr>
<tr>
<td>ST-segment depression, mV</td>
<td>0.08±0.03</td>
</tr>
<tr>
<td></td>
<td>0.22±0.08</td>
</tr>
<tr>
<td>ABP systolic, mmHg</td>
<td>125.7±2.85</td>
</tr>
<tr>
<td></td>
<td>151.1±5.51</td>
</tr>
<tr>
<td>ABP diastolic, mmHg</td>
<td>82.5±1.64</td>
</tr>
<tr>
<td></td>
<td>57.5±2.89</td>
</tr>
<tr>
<td>JT/RR</td>
<td>0.342±0.01</td>
</tr>
<tr>
<td></td>
<td>0.440±0.01</td>
</tr>
<tr>
<td>Velocity of adaptation, %</td>
<td>21.4±1.33</td>
</tr>
</tbody>
</table>

HR – heart rate; ABP – arterial blood pressure. Values are expressed as mean±standard error.

Table 2. The values in velocity of adaptation ($V_{sa}$) of cardiovascular system at onset a Roufier’s test (aerobic workout), 30-second all-out test in jumping (anaerobic workout) and bicycle ergometry (graded stress)

<table>
<thead>
<tr>
<th>Group</th>
<th>Exercise test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roufier’s test</td>
</tr>
<tr>
<td>Non-sportsmen</td>
<td>21.4±1.33</td>
</tr>
<tr>
<td>Endurance group</td>
<td>19.8±1.34</td>
</tr>
<tr>
<td>Sprint group</td>
<td>16.3±1.33</td>
</tr>
<tr>
<td>Combat sports group</td>
<td>17.2±1.29</td>
</tr>
</tbody>
</table>

Values are expressed as mean±standard error.

lization 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 two common misconceptions in the exercise science and coaching professions (9). First, that the energy systems respond to the demands of intense exercise in an almost sequential manner, and second, 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 contributions are derived from the anaerobic and aerobic energy systems occurs considerably earlier than has traditionally been suggested (9–11). We must point out that the last year studies have shown a great importance of complexity in body functioning (8, 12). Since

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Mobilization of cardiovascular function during the various exercise tests
(maximal values in change the ratio JT interval and RR interval (JT/RR))

**Fig.** Mobilization of cardiovascular function during the constant-load and all-out exercise tests

The cardiovascular system is one of the constituent parts and a holistic system of the body therefore the reactions of cardiovascular system to constant-load tests or all-out tests allow one to assess the functional capabilities and functional peculiarities of the body (8). 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. The main differences in the content of training between the sprint and endurance cohorts consist in prevailing the interval methods of training in sprint cohort and sustained exercise in endurance events (13). Sudden change in intensity in workloads during the fight is typical characteristic of combative events. Thus, these changes could be possible explanation of differences in values of the velocity of adaptation between the endurance and sprint or dualist cohorts found out during this study.

Individual peculiarities and differences between various cohorts can be assessed making use of the index of velocity of adaptation (V_{ad}), which represents the difference between the relative changes of JT and RR intervals of ECG. Our previous studies (14, 15) have shown that the velocity of adaptation at onset of exercise depends rather on the functional state or residual effects of training than on the type of exercise-test. During the study designed to evaluate the changes in velocity of adaptation in sprint cohort significant changes under the influence of concentrated heavy training loads have been found, i.e. 16.3±1.33% before training, 26.2±1.42%—after 2 weeks of heavy training, and 20.1±1.35%—after one week of recovery, accordingly (14). All this allows us to conclude that individual peculiarities and differences between cohorts in velocity of adaptation of cardiovascular system at onset of exercise can be evaluated making use of the difference between the relative changes of RR and JT intervals of ECG.

When assessing individual peculiarities of the body functioning during the workloads it is important to evaluate at what extent the body function was mobilized 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 mobilization of cardiovascular system occurred (8, 15, 16). A special study performed by V. G. Bochkov in 1986 (17), has shown that activation of physiological systems could be expressed by normalized values in ratio of underlying indices of the physiological system. These underlying indices of cardiac function can be the ratio of JT and RR intervals (16). The JT interval is not dependent on the ventricular depolarization pattern and can be used as an accurate means of following the duration of ventricular repolarization (18) and its changes interrelate with the changes in the intensity of metabolism (16). The results obtained during this study have shown that the ratio of JT/RR can be useful for outlining at what extent a cardio-
vascular function was mobilized. 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 V. G. Bochkov in 1986. Accordingly to V. G. Bochkov these biological constants can be expressed mathematically (1/e=0.368 and 1−1/e=0.632). When performing dosed workloads (Roufier’s 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.

Concluion
1. The change in ratio of JT/RR intervals of electrocardiogram allows one to assess the dynamics of mobilization of cardiovascular system during the exercise tests or workouts.

2. The greater mobilization of cardiovascular system when performing constant-load exercise tests is rather characteristic for non-athletes than sportsmen’s cohorts. Constant-load exercise tests rather than all-out exercise tests are more suitable for assessments of individual peculiarities or differences between the cohorts.

3. The individual peculiarities in velocity of adaptation of cardiovascular system at onset of exercise can be evaluated by making use of the index of velocity of adaptation (V-ad), which represents the difference between the relative changes of RR and JT intervals of ECG. Velocity of adaptation at onset of exercise depends on the residual effects of training but not on the type of exercise-test.

Širdies ir kraujagyslių sistemos funkcijos aktyvėjimo ypatybės darant dozuario ir maksimalaus fizinio kūrio mėginius

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Raktažodžiai: širdies ir kraujagyslių sistema, EKG analizė, fizinio kūrio mėginių.


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References
4. Rothe CF, Gersting JH. Cardiovascular interaction; an

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