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Cardiovascular changes during the performance by nonathletes of Bosco repeated jumps anaerobic test

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ABSTRACT

Objective: The aim of this study was to find out the characteristics of cardiovascular changes when performing Bosco repeated jumps anaerobic test depending on the duration of jumping in a nonathletes cohort.

Materials and methods: Changes in arterial blood pressure indices and changes in 12-lead ECG indices were analyzed. The characteristics of recovery after workloads were assessed by evaluating the time of half period of recovery of registered indices and by the Lyapunov exponent.

Results: The results have shown that the ratio of JT and RR intervals of ECG (JT/RR) can be useful for outlining to what extent a cardiovascular function was mobilized. The mobilization of cardiovascular function when performing a 30-s jump test changed up to 0.454 ± 0.012 and when performing a Bosco test, up to the maximal values, i.e. 0.634 ± 0.004 . When performing jumps of maximal intensity, a maximal change of JT/RR occurrence was between 50 and 60 s. The increasingly serious myocardial ischemic episodes were observed at the onset of the jumping task. The duration of 60-s of all-out jump test has made an influence on the stability of the recovery processes of cardiovascular indices, i.e. the nonexponential type of recovery was observed.

Conclusions: When performing Bosco 60-s repeated jumps in an anaerobic test, a maximal mobilization of the cardiovascular system occurs between 50 and 60 s. The 30-s all-out test duration in jumping is enough to outline at what extent cardiovascular function was mobilized as well as to assess other functional characteristics during high intensity intensive exercising.

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1. Introduction

At the onset of exercise the cardiovascular system adapts itself with a series of integrated responses to meet the metabolic demands of exercising muscles [1]. Since the cardiovascular system is one of the constituent parts of the holistic system of the body, the reactions of the cardiovascular system to constant-load tests or all-out tests allow assessing the functional capabilities and functional characteristics of the body [2–4]. Anaerobic tests are designed to measure anaerobic power and anaerobic capacity [5]. The development of simple, noninvasive tests of work capacities, underpinned primarily by anaerobic metabolism, proliferated in the early 1970s. A 30-s 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 [6]. However, 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 was applied to evaluate human anaerobic power and capacity [7]. The Bosco test also may be inappropriate for individuals who are not well trained in jumping [7]. The objective of this study was to find out the characteristics of cardiovascular changes when performing the Bosco repeated jumps anaerobic test depending on the duration of jumping in a nonathletes cohort.

2. Materials and methods

The subjects of this study were 11 volunteer male students who were not engaged in sports training with a mean age of 20.9 years (SEM, 1.21) and body mass index of 22.3 kg/m² (SEM, 0.38). Three tests were performed: a Roufier test (30 squats per 45 s), a 60-s Bosco repeated jumps anaerobic test, and a 30-s all-out repeated jumps test. The jumps were conducted on a force platform. In order to prevent venous pooling the subjects underwent 10 s squats after finishing the jumps and sat still during the next 3 min of the recovery. Indirect arterial blood pressure (ABP) measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff before exercise test and after exercise during the first 3 min of recovery. A computerized ECG analysis system “Kaunas-load” 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 evaluation the changes of JT interval – (JT_i/JT₀)100% in comparison with the changes of RR interval – (RR_i/RR₀)100% as a difference,

$$V_{Ad} = \left(\frac{JT_i}{JT_0} \right) 100\% - \left(\frac{RR_i}{RR_0} \right) 100\%,$$

where V_{Ad} indicates index velocity of adaptation; JT₀ and RR₀, values of intervals before exercising; JT_i and RR_i, values of

intervals at onset of exercising, i.e., averaged measurement during the first 10 s.

This difference was accepted as the index of the velocity of adaptation of the cardiovascular system in response to load.

The characteristics of recovery after workloads were assessed by evaluating the time of half period of recovery ($t_{1/2}$) of registered indices and second, by the Lyapunov exponent (LE):

$$LE = \frac{1}{N} \sum_{i=1}^N \ln \left(\frac{X_{i+1}}{X_i} \right),$$

where X indicates discrete signal values of moments in time; $N \in \mathbb{N}$ (set of natural numbers).

The obtained value of LE was accepted as an indicator of stability in the whole process of recovery [8].

The relationships between parameters were assessed using Spearman correlation. The significance of the difference between values was evaluated by computing t criterion, i.e., the paired t test was used. The difference was considered statistically significant when P was <0.05 .

3. Results

At the onset of repeated jump test abrupt changes of cardiovascular indices occurred. Figure 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 the dynamics of cardiovascular indices during the first 30 s of jumping were found. If the maximal values registered at the end of both jumps tests were compared, it becomes obvious that 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 dynamics of ABP after the performance of 30-s and 60-s all-out repeated jumps anaerobic tests is presented in Table 1. The comparison of these two exercise tests did not reveal any essential differences except for the fact that bigger changes in systolic ABP ($P < 0.05$) and slower recovery in the performance of 60-s all-out repeated jumps were observed ($P < 0.05$).

The velocity of adaptation at the onset of exercise tests was assessed making use of the index of velocity of adaptation (V_{Ad}). The data obtained during the study are presented in Table 2. No statistically significant difference in V_{Ad} obtained during various exercise tests ($P < 0.05$) was found.

The results obtained during this study showed 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 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 up to the maximal values, i.e. 0.634 ± 0.004 . We must point out that when performing jumps of maximal intensity, maximal changes of JT/RR occurrence was between 50 and 60 s.

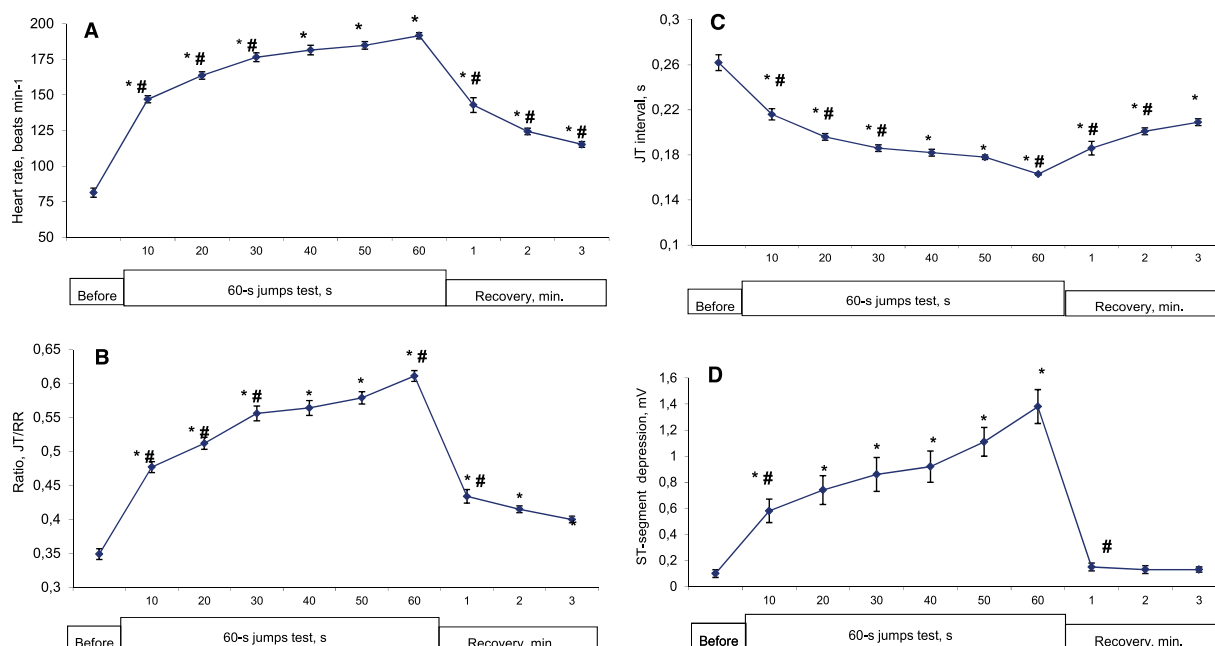


Figure – Dynamics of ECG indices while performing a Bosco 60 s repeated jump test (time scale in seconds) and during the recovery (time scale in minutes). (A) Heart rate, beats min⁻¹; (B) ratio JT/RR intervals; (C) JT interval; and (D) ST-segment depression. Values are mean \pm SE. * $P < 0.05$ as compared with the value before physical load; # $P < 0.05$ between the values of the two side by side.

Table 1 – Dynamics of arterial blood pressure (ABP) after performance of 30-s and 60-s all-out repeated jumps anaerobic tests.

Exercise test	Indices	Before exercise	After workload		
			1 min	2 min	3 min
Roufier test	ABP systolic, mmHg	124.8 \pm 3.2	155.3 \pm 2.7 ^{*,**}	138.5 \pm 3.6 ^{*,**}	126.3 \pm 3.2 ^{**}
	ABP diastolic, mmHg	73.6 \pm 1.4	50.1 \pm 3.2 ^{*,**}	68.7 \pm 3.3 ^{*,**}	70.9 \pm 3.6 ^{**}
30-s jump test	ABP systolic, mmHg	125.3 \pm 3.4	172.8 \pm 3.4 [*]	152.5 \pm 4.1 [*]	146.3 \pm 3.5 [*]
	ABP diastolic, mmHg	77.1 \pm 1.1	24.1 \pm 4.6 [*]	49.2 \pm 4.5 [*]	60.2 \pm 4.6 [*]
Bosco test (60-s jump)	ABP systolic, mmHg	125.7 \pm 3.4	185.3 \pm 3.2 ^{*,**}	178.7 \pm 2.8 ^{*,**}	163.5 \pm 3.5 ^{*,**}
	ABP diastolic, mmHg	76.5 \pm 1.1	16.6 \pm 5.7 [*]	37.4 \pm 4.7 [*]	43.2 \pm 5.9 ^{*,**}

* $P < 0.05$ compared to before exercise.
 ** $P < 0.05$ compared to 30-s jump test.

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

Exercise test	V_{Ad} (%)	$1/2T_{HR}$ (s)	$1/2T_{JT}$ (s)	$1/2T_{JT/RR}$ (s)	$1/2T_{(S-D)/S}$ (s)
Roufier test	19.2 \pm 1.4	28.1 \pm 1.7	48.1 \pm 1.8	25.3 \pm 1.8	60.6 \pm 3.2
30-s jump test	20.3 \pm 2.0	61.7 \pm 3.6 [*]	81.6 \pm 3.5 [*]	40.1 \pm 2.1 [*]	87.8 \pm 3.4 [*]
Bosco test (60-s jump)	20.6 \pm 2.8	82.1 \pm 4.1 ^{*,**}	96.2 \pm 4.2 ^{*,**}	52.5 \pm 2.3 ^{*,**}	110.3 \pm 3.9 ^{*,**}

V_{Ad} , velocity of adaptation; $1/2T$, half recovery time; HR, heart ratio; JT, JT interval of electrocardiogram; JT/RR, ratio of intervals RR and JT of electrocardiogram; (S – D)/S, relative arterial blood pressure (S, systolic; D, diastolic).
 * $P < 0.05$ compared to Roufier test.
 ** $P < 0.05$ compared to 30-s jump test.

The recovery of cardiovascular indices after the exercise tests used was assessed by the evaluation of half period of recovery time i.e. $1/2T$. Table 2 presents the data of recovery after various exercise tests. The slowest recovery of cardiovascular indices was observed after the Bosco test (60-s all-out

anaerobic test). The analysis of correlations between a half period of recovery times after 30-s duration and 60-s duration of repeated jump tests showed the following values of correlation: $r = 0.68$ for $1/2T_{HR}$, $r = 0.71$ for $1/2T_{JT}$, and $r = 0.65$ for $1/2T_{JT/RR}$. All these correlations were statistically significant

Table 3 – Characteristics of recovery of cardiovascular indices after exercise tests.

Exercise test	LE _{HR}	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*

LE, Lyapunov exponent; HR, heart ratio; JT, JT interval of electrocardiogram; JT/RR, ratio of intervals RR and JT of electrocardiogram; (S – D)/S, relative arterial blood pressure (S, systolic; D, diastolic).

* P < 0.05 compared to Roufier test.

** P < 0.05 compared to 30-s jump test.

(P < 0.05) and indicated the similarities between the two jumps tests concerning the assessment of individual characteristics of recovery.

Table 3 presents the values of Lyapunov exponent (LE) obtained in the process of analysis of the dynamics of indices registered during the recovery. Statistically significant differences between the values of LE_{HR} obtained after Roufier test and 60-s repeated jump test (P < 0.05), between the values of LE_{HR} obtained after 30-s and 60-s repeated jump tests (P < 0.05), as well as between values of LE_{JT/RR} obtained after Roufier test and 60-s 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 was a positive or negative sign of LE. The negative sign indicated the stability in the process, i.e. in the dynamics of the indices during the recovery and the positive sign indicated instability that could be due to some discoordination of the correspondent mechanisms. The tinted panes in Table 3 mark the cases where the LE was 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.

4. Discussion

One of questions that remain open to discussion concerning the use of cardiovascular indices for the assessment of body functioning during the single bouts of maximal exercise is the interaction and relative contribution of the three energy systems (creatine phosphate, glycolytic and oxidative phosphorylation). We must point out that a lot of studies have shown a great importance of complexity in body functioning [2,9–12]. Given repeated reproduction over the years, these early attempts have led to 2 common misconceptions in the commonly accepted understanding about energy regeneration processes during exercising [5]. 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 periods. 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 system occurs is considerably earlier than has traditionally been suggested [5,13,14].

Mobilization of the cardiovascular system depends on the type of exercising as well as its duration [1,6,18]. In this study

the Roufier test was used as a dosed aerobic exercise test [18] and the other two tests were anaerobic exercise tests of maximal intensity [5,7]. The difference in cardiovascular changes during anaerobic exercising was the main object of this study. The difference between the last two tests was in the duration of the jumping task and it was the main reason for cardiovascular changes of different magnitudes during this type of exercising. The results obtained during the study showed that the velocity of adaptation at onset of exercising (V_{Ad}) did not depend on the type of exercising (Table 2). No statistically significant difference in V_{Ad} obtained during various exercise tests was found. These results confirmed the fact established in our previous studies [18,19] that the velocity of adaptation at onset of exercise depends rather on the functional state than residual effects of training. The changes of other analyzed ECG indices differed significantly and the duration of the jumping tasks was the most important factor.

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 [2,15–17]. The ST-segment depression at the end of the Bosco test indicates transient, functional ischemic processes in cardiac muscle that could be taken as heart function limiting failure during the load.

The studies designed to assess the individual characteristics of body functioning during the workloads usually have a task to evaluate to 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 the cardiovascular system occurred [2,18,19]. A special study [20] has shown that activation of physiological systems could be described by normalized values in respect to underlying indices of the physiological system. These underlying indices of cardiac function can be the ratio of JT and RR intervals [2,18,21]. The JT interval is not independent of the ventricular repolarization pattern and can be accurate measure in estimating the duration of ventricular depolarization [22,23] and its changes interrelate with the intensity of heart metabolism [2]. Some studies showed that changes in ratio of JR/RR intervals of ECG allowed assessing the dynamics of mobilization of the cardiovascular system during the exercise tests or workouts [18,19,21]. The results obtained during this study confirmed

the same idea, i.e. that the ratio JT/RR can be useful for outlining to what extent a cardiovascular 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 varied very closely or even coincided as it was established earlier [20]. When performing dosed workloads (Roufier test – aerobic workout) and during 30-s 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. This is evidence, as the ratio of JT and RR intervals (JT/RR) of ECG provides the information concerning the dynamics of mobilization of the cardiovascular system during the workouts. When performing jumps of maximal intensity a maximal change of JT/RR occurrence was between 50 and 60 s. Thus a shorter than 60 s jump exercise test can be more useful for the assessment of the characteristics of mobilization of cardiovascular function in a nonathlete cohort. 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.

A decrease in the complexity of functioning of the cardiovascular system of nonathletes after 60-s all-out jumps was most evident in relational values of ECG as JT/RR and ABP such as relative pulse pressure $(S - D)/S$. It means that the duration of 60-s of all-out jump test made a negative influence on the stability of the recovery processes of cardiovascular indices, and the nonexponential type of recovery was observed. Summarizing these findings, also the increasingly serious myocardial ischemic episodes observed during the performance of the jumping task with maximal efforts we can conclude that 60-s all-out vertical jumps test (Bosco test) is a very difficult task and should be used for the assessment of performance abilities of only well-trained athletes.

5. Conclusions

An increasingly serious myocardial ischemic episode during the performance of the jumping task of maximal intensity is a future of cardiovascular changes in a nonathlete cohort. When performing Bosco 60-s repeated jumps in an anaerobic test, a maximal mobilization of the cardiovascular system occurs between 50 and 60 s. The 30-s all-out test duration in jumping is enough to outline at what extent cardiovascular function was mobilized as well as to assess other functional characteristics during high intensity exercising.

Conflict of interest

The authors declare that they have no conflicts of interest.

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