

# RATE OF INCREASE IN WORKLOAD DETERMINES THE MOBILIZATION RATE BUT NOT THE DEGREE OF INCREASE IN ECG PARAMETERS

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## ABSTRACT

*Background.* The aim of this study was to compare the peculiarities of the dynamics of cardiovascular functional state indices during bicycle ergometry by applying the steep or slow increase in workload.

*Methods.* Twenty five males attending health promotion sport clubs took part in two cardiovascular testing procedures by performing graded exercise stress, i.e. increase in workload every 1 min, and increase in workload every 6 min, and they exercised till the inability to continue the task or unless distressing cardiovascular symptoms supervened; 12 lead ECG was recorded and analysed.

*Results.* The steep increase of registered cardiovascular parameters was observed at onset of exercising and the rate of was in dependence on the rate of the increase in workload. Registered maximal changes of heart rate, JT interval, and the ratio JT/RR as functional state indices at the moment of refusing to continue the graded exercise test were at the same level while applying the steep or slow increase in workload.

*Conclusions.* The rate of increase in workload determines the mobilization rate but not the degree of increase of ECG parameters. Maximal changes of heart rate, JT interval, and the ratio JT/RR as functional state indices at the moment of refusing to continue the graded exercise test were at the same level while applying the steep or slow increase in workload.

**Keywords:** cardiovascular system, graded exercise stress, functional state.

## INTRODUCTION

At the onset of exercise a lot of body systems adapt to the variations of load. Consequently, a number of indices exist for the measurement of response of body functions to workload. In practice, the response to exercise can be evaluated by measuring the changes in the performance of one or another system (Cao et al., 2015; Giardini, Odendaal, Khambadkone, & Derrick, 2011; Hettinga, Monden, van Meeteren, & Daanen, 2014; Hughson & Tschakovsky, 1999; Roberts, 2014; Vainoras, 2002).

There are a lot of studies presenting the dynamics of cardiovascular indices during graded exercise stress (Alihanoglu et al., 2015; Ceci et al., 2013; Olson et al., 2012; Shin, J. I. Park, S. K. Park, & Barrett-Connor, 2014; Vainoras, 2002).

Concerning the problem of evaluation of the peculiarities in mobilization of body functioning during exercising, the two factors are important: first, the velocity of adaptation at onset of exercise, and second, to what extent the body function was mobilised.

The various protocols for increase in workload during the graded exercise stress could be used. The steep increase in workload induces the faster development of fatigue while the slow increase in workload allows slow adaptation to exercising and demonstration of the best results of muscular performance (Dawson et al., 2005; Munch et al., 2014; Poderys, Buliuolis, Poderytė, & Sadzevičienė, 2005). The aim of this study was to compare the peculiarities in dynamics of cardiovascular

functional state indices during bicycle ergometry by applying the steep or slow increase in workload.

## METHODS

The participants of the study (males attending health promotion sport,  $n = 25$ ) had spent 20 min seated and after registration the base-line values of cardiovascular indices underwent a 50 W increase in workload, i.e. graded exercise test (*bicycle ergometry*) and they exercised till the inability to continue the task or unless distressing cardiovascular symptoms supervened. The subjects underwent a 50W increase in workload every 60 seconds (60 revolutions/min). Two protocols for increase in workload were applied. First, increase in workload every 1 min, and the second, increase in workload every 6 min.

A computerized ECG analysis system "Kaunas-load" was applied for 12 lead ECG recording and analysis. The changes in heart rate (HR), JT interval, and in the ratio of intervals JT/RR were analysed. Standard ABP measurement was performed with pneumatic cuff by listening to "Korotkoff tones".

The significance of the difference between the values was evaluated by computing  $t$  criterion; the paired  $t$ -test was used. The difference has been considered statistically significant at  $p < .05$  (95 CI).

## RESULTS

**Working capacity.** The task for the participants of this study was to continue exercising as much as they can, i.e. till the inability to continue it. Table 1 presents the data of working capacity while the two incremental protocols were used. All the participants of this study were able to continue the task, i.e. to perform the exercise up to 250 W (5 min), some of them were able to perform the exercise at the stage of 350 W (up to 7 min) while the new stage of increased workload was 1 minute. While the new stage of increased workload was 6 minutes, all participants were able to perform the exercise up to 150 W (18 min), some of them were able to perform it at the stage of 350 W (up to 32 min).

**Dynamics of cardiovascular indices.** Figure 1 presents the dynamics of HR during the graded exercise test applying two protocols of the increase in workload. There were no significant differences ( $p > .05$ ) between the initial values before exercising. The steep increase in HR was observed at onset of exercising and the rate of was in dependence on the rate of increase in workload. There were no statistically significant differences ( $p > .05$ ) between maximal HR values registered at the end of the exercising ( $176.7 \pm 3.9$  beats/min while the increase in workload every 1 min was applied and  $169.5 \pm 4.6$  beats/min while the increase in workload every 6 min was applied).

Table 1. Working capacity while two different protocols for increase in workload was applied

Indices	Increase in workload every 1 min								
	Workload	50 W	100 W	150 W	200 W	250 W	300 W	350 W	
Total duration of exercising	1 min	2 min	3 min	4 min	5 min	6 min	7 min		
Number of participants	25	25	25	25	25	16	4		
	Increase in workload every 6 min								
Workload	50 W			100 W			150 W		
Total duration of exercising	2 min	4 min	6 min	8 min	10 min	12 min	14 min	16 min	18 min
Number of participants	25	25	25	25	25	25	25	25	25
	200 W			250 W			300 W		
Total duration of exercising	20 min	22 min	24 min	26 min	28 min	30 min	32 min		
Number of participants	16	11	8	6	4	4	2		

Figure 2 presents the dynamics of JT interval of ECG during the graded exercise test applying two protocols of increase in workload. There were no significant differences ( $p > .05$ ) between durations of JT intervals registered before exercising. At onset of exercising and the rate of changes was in dependence on the rate increase in workload. There were no statistically significant differences ( $p > .05$ ) between the shortest JT interval values

registered at the end of the exercising ( $0.162 \pm 0.005$  s while the increase in workload every 1 min was applied and  $0.164 \pm 0.004$  s while the increase in workload every 6 min was applied).

Similar changes as a HR changes were find in comparison with the dynamics of the ratio of ECG intervals JT/RR during the graded exercise test applying two protocols of increase in workload. There were no statistically significant differences

Figure 1. HR dynamics during the graded exercise test applying two protocols of increase in workload

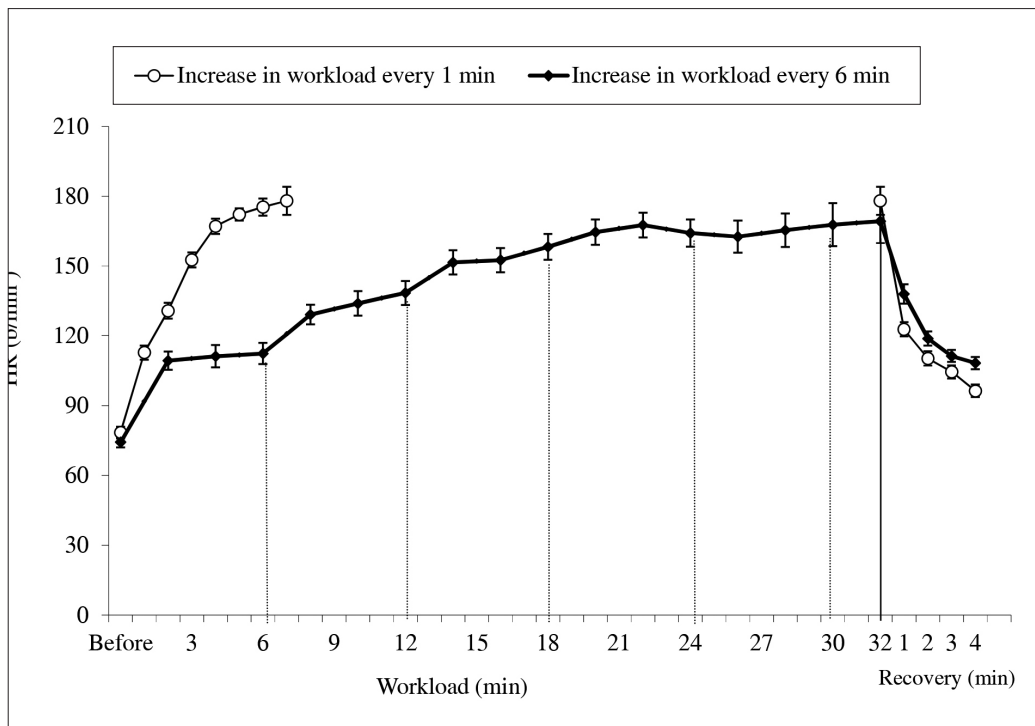
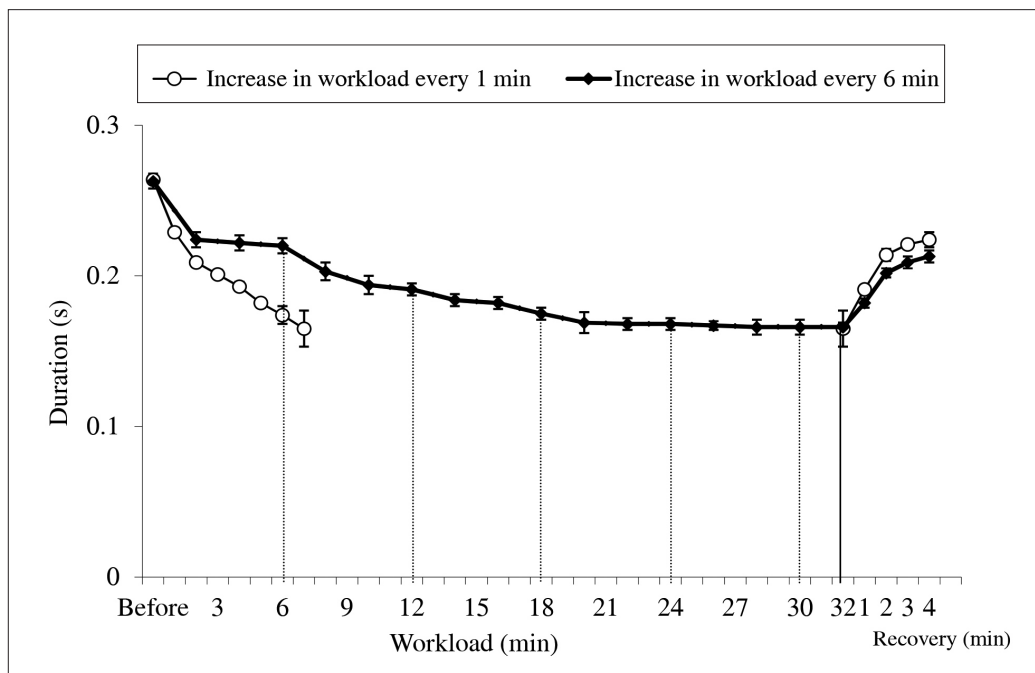


Figure 2. JT interval dynamics during the graded exercise test applying two protocols of increase in workload



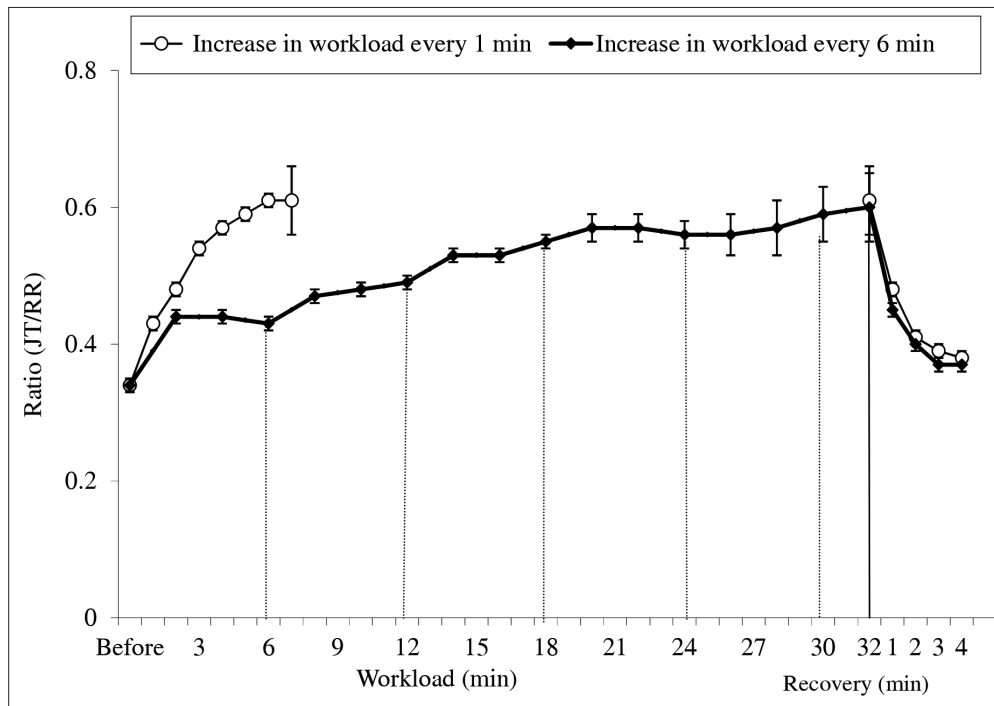


Figure 3. Dynamics of ratio of ECG intervals JT/RR during the graded exercise test applying two protocols of increase in workload

Indices	Before workload		At the end of workload	
	Increase in workload every 1 min	Increase in workload every 6 min	Increase in workload every 1 min	Increase in workload every 6 min
HR (beats/min)	78.5 ± 2.5	74.3 ± 2.2	176.7 ± 3.9	169.5 ± 4.6
JT interval (s)	0.264 ± 0.003	0.263 ± 0.005	0.162 ± 0.005	0.164 ± 0.004
JT/RR	0.342 ± 0.01	0.34 ± 0.01	0.610 ± 0.01	0.616 ± 0.04
Systolic ABP (mmHg)	124.0 ± 2.1	126.2 ± 2.1	185.8 ± 6.8	204.2 ± 6.3
Diastolic ABP (mmHg)	75.6 ± 1.5	77.6 ± 1.3	23.3 ± 5.6	29.2 ± 6.7
Total peripheral resistance (mmHg/l/min)	16.8 ± 1.3	16.0 ± 1.4	3.8 ± 0.7	2.7 ± 1.0

Table 2. Values of ECG indices registered during the graded exercise stress while two different protocols were applied

( $p > .05$ ) between the JT/RR values registered at the end of the exercising ( $0.610 \pm 0.01$  while the increase in workload every 1 min was applied and  $0.616 \pm 0.04$  while the increase in workload every 6 min was applied).

In general, the dynamics of cardiovascular parameters while performing the graded exercise stress has the same tendency of stepwise changes with each new stage of workload. This tendency was strongly expressed during the first stages of workout and weakened when exercising became subjectively hard, i.e. during the last stages of workout. The values of cardiovascular indices registered at rest and at the moment of their

maximal change, usually at the end of exercising, are presented in Table 2. As it was established during the analysis of figures presented in Table 2, a statistically significant difference was found ( $p < .05$ ) while the values of systolic ABP at the end of exercising were compared. There were no significant differences observed between other registered ECG indices at the end of exercising.

## DISCUSSION

Various indices for outlying cardiovascular response to exercising and physical exertion have been suggested; their applicability and value

are widely discussed and analyzed in research literature (Boettger et al., 2010). Dynamics of HR during exercising is a commonly accepted measure of intensity of exercising and provides the clear understanding of the dynamics of functional state. HR is easily measurable index and various types of heart rate monitors have been widely used in sports for over 30 years (Achten & Jeukendrup, 2003). Some authors consider the HR response measurement as a convenient non-invasive evaluation tool to monitor and analyze individual workouts (Dellal et al., 2012; Hettinga et al., 2014; Jeukendrup & VanDiemen, 1998). Increases in the severity of exercise leads to increases in HR until it reaches its maximum, which is relatively constant in a particular person.

JT interval is not independent of the ventricular repolarisation pattern and can be used as an accurate means of estimating the duration of ventricular depolarisation (Banker, Dizon, & Reiffel, 1997; Chiladakis et al., 2012) and its changes interrelate with the intensity of heart metabolism (Vainoras, 2002). In some studies it was shown that the change in the ratio of JT/RR intervals of ECG allows assessing the dynamics of mobilization of cardiovascular system during the exercise tests or workouts (Ežerskis, 2005; Poderys et al., 2005; Žumbakytė-Šermukšnienė, Kajenienė, Vainoras, Berškienė, & Augutienė, 2010). The results obtained in this study confirm the same idea, i.e. the ratio of JT/RR can be useful for outlining to what extent the 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 with what was established by Boshkow (Бочков, 1986). According to Boshkow (Бочков, 1986), these biological constants can be expressed mathematically ( $1/e = 0.368$  and  $1-1/e = 0.632$ ). When performing dosed workloads (*Rouffier test* – aerobic workout) and during 30-second all-out test in jumping (anaerobic workout), the changes in ratio of JT/RR were in dependence on the performance abilities (training experience) and functional state. This is evidence that the ratio of JT and RR intervals (JT/RR) of ECG provides the information concerning the dynamics of mobilization of cardiovascular system.

Changes of various cardiovascular indices during graded exercise stress could be useful for outlining the peculiarities of functioning and personal features of cardiovascular system (Alihanoglu et al., 2015; Ceci et al., 2013; Olson et al., 2012; Shin et al., 2014; Vainoras, 2002). The results obtained during this study showed that maximal changes of HR, JT interval, and the ratio of JT/RR as functional state indices at the moment of refusing to continue the graded exercise test were of the same level while applying the steep or slow increase in workload.

## CONCLUSION

The rate of increase in workload determines the mobilization rate but not the degree of increase of ECG parameters.

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