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MUSCULAR PERFORMANCE, CARDIOVASCULAR CHANGES OF CENTRAL AND PERIPHERAL INDICES DURING THE INCREMENTAL BICYCLE ERGOMETRY

MIŠIĆNA IZVEDBA, PROMJENE SREDIŠNJIH I PERIFERNIH KARDIOVASKULARNIH PARAMETARA TIJEKOM INKREMENTALNE BICIKL ERGOMETRIJE

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SUMMARY

Muscle activity is the factor which may change cardiovascular system activity at the highest degree and the most rapidly. Changes in cardiovascular function shift in accordance with the alteration of physical load to the maximum. The aim of this study was to find out the differences in dynamics of central and peripheral cardiovascular parameters in dependance of functional preparednes during the incremental bicycle ergometry. All the subjects underwent a computerized bicycle exercise stress test. Participants was devided into two subgroups: of higher and lower physical performance: sub-group A of subjects, who were able to perform the load of 250 W and higher (*sub-group A of higher physical performance*); and sub-group B of subjects, who were able to perform the load of less than 250 W (*sub-group B of lower physical performance*).

A computerized ECG analysis system "Kaunas-load" was employed for continuous 12 synchronous lead ECG recording and analysis. Heart rate (HR) were analyzed. Indirect arterial blood pressure (ABP) measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff before, at the end of each minute during the workload and recovery. Oxygen saturation (StO_2) and blood flow in muscle (m. vastus lateralis) was recorded by near-infrared spectroscopy (NIRS). Conclusion. During stepwise incremental workload to failure, the differences of functional preparedness can be observed only during the initial stages of exercising (dosed workload), but when the load became subjectively heavy, i. e. at the last testing stages (maximum workload), differences between central cardiovascular functional parameters were not found, and in contrast, differences between peripheral cardiovascular functional parameters were more observable oncoming to the maximum load: increasing workload decreased the blood flow and oxygen saturation of active muscle.

Key words: workload, cardiovascular system, central and peripheral functional parameters

SAŽETAK

Mišićna aktivnost je čimbenik koji najbrže i u najvećoj mjeri može promijeniti aktivnost kardiovaskularnog sustava. Promjene kardiovaskularnih funkcija mijenjaju se u skladu s promjenom fizičkog opterećenja do maksimuma. Cilj ovog istraživanja bio je utvrditi razlike u dinamici središnjih i perifernih kardiovaskularnih parametara ovisno o funkcionalnoj pripremljenosti tijekom inkrementalne bicikl ergometrije. Svi ispitanici podvrgnuti su računalnom stres testu vježbe na biciklu. Sudionici su podijeljeni u dvije podskupine: više i niže tjelesne izvedbe: ispitanici u podskupini A, koji su u mogućnosti obavljati opterećenje od 250W i više (pod-skupina A visoke tjelesne izvedbe); i ispitanici podskupine B, koji su bili u mogućnosti izvršiti opterećenje manje od 250 W (podskupina B niže tjelesne izvedbe).

Korištena je računalna EKG analiza sustava "Kaunas opterećenja" za stalno 12 - kanalno EKG snimanje i analize. Analizirana je frekvencija srca (HR). Neizravna mjerenja arterijskog krvnog tlaka (ABP) napravljena su na ruci sa sfigmomanometarom i manžetom standardne veličine na ruci prije, na kraju svake minute tijekom opterećenja i tijekom oporavka. Zasićenja kisikom (StO_2) i protok krvi u mišićima (m. vastus lateralis) zabilježeni su bliskom infracrvenom spektroskopijom (NIRS).

Tijekom postupnog inkrementalnog opterećenja do otkaza, razlike u funkcionalnoj pripremljenosti mogu se vidjeti samo tijekom početne faze vježbanja (doziranog opterećenja), ali kada opterećenje postaje subjektivno teško, odnosno u posljednjoj fazi ispitivanja (maksimalno opterećenje), razlike između središnjih kardiovaskularnih funkcionalnih parametara nisu pronađene, dok su razlike između perifernih kardiovaskularnih funkcionalnih parametara bile vidljive blizu maksimalnog opterećenja: povećanje opterećenja smanjilo je zasićenost kisikom i protok krvi u aktivnim mišićima.

Ključne riječi: opterećenje, kardiovaskularni sustav, središnji i periferni funkcionalni parametri.

INTRODUCTION

The body's functional state and functional fitness and a number of studies of regulatory mechanisms of functional systems are carried out by monitoring the reactions induced by functional tests or exercises. The functional state of the body can be estimated by changes in functional parameters (Wilkinson et al., 2009) during the dosed maximal exercise tests. Muscle activity is the factor which may change cardiovascular system activity at the highest degree and the most rapidly.

Physical load resulting changes in body's function - this is not a change of the state in a single body's system, but it's a whole set of complex and interrelated processes (Biggiero, 2001; Bikulciene et al., 2009). In such a chain of processes concatenations of cardiovascular, the central and peripheral regulatory mechanisms play an important role (Delp, 1999; Jones, Pole, 2007). Due to increasing body's metabolic needs many cardiovascular events begin almost at the same time in order to ensure sufficient supply of oxygen (Hughson, 2007). Changes in cardiovascular function shift in accordance with the alteration of physical load to the maximum. Neither a single blood flow's regulatory mechanism does not work in isolation, but interacts with a whole system or performs as a part of regulatory system; hence it is important to perceive these interactions occurring during exercise. Since varying types of physical workloads activate different physiological system activity at different degree. The aim of this study was to find out the differences in dynamics of central and peripheral cardiovascular parameters in dependance of functional preparednes during the incremental bicycle ergometry.

SUBJECTS AND METHODS

The participants of the study were 27 healthy voluntary mans (age – 22±9 yr, KMI – 25.3±3.2). All the subjects underwent a computerized bicycle exercise stress test. A short-term provocative research protocol was used. The initial workload performed by all the subjects was 50 W, and it was increased by 50 W every minute up to submaximal power was reached. The frequency of pedaling was 60 rotations/min. Participants were divided into two subgroups: sub-group A of subjects, who were able to perform the load of 250 W and higher (*sub-group A of higher physical performance*); and subgroup B of subjects, who were able to perform the load of less than 250 W (*sub-group B of lower physical performance*). A computerized ECG analysis system "Kaunas-load" was employed for continuous 12 synchronous lead ECG recording and analysis. Heart rate (HR) were analyzed. Indirect arterial blood pressure (ABP) measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff before, at the end of each minute during the workload and recovery. Oxygen saturation (StO2) and blood flow in muscle (m. vastus lateralis) was recorded by near-infrared spectroscopy (NIRS) using a device Standard System Model 325 (Hutchinson Technology). Changes in NIRS were used estimate the profiles of peripheral blood flow of the active muscle microvasculature and was calculated by the following equation (Beekvelt et.at., 2001):

$$BF=(((t_{Hb} x60)/(([Hb]x1000)/4))x1000/10 \text{ (ml/min/100 cm}^3\text{)}$$

where: t_{Hb} – oxidized/de-oxidized hemoglobin (μM/s); [Hb] – molecular – weight hemoglobin (64.458 g/mol). Statistical analysis of the data. Analysis was conducted using statistical package *SPSS for Windows 17.0*. Standard statistical method were used to calculate means and standaed deviation (±SD). A one-way analysis of variance (ANOVA) was used to establish the differences between the measurements. The difference in mean was regarded as statistically significant when error probability with respect to criteria was $P<0.05$.

RESULTS AND DISCUSSION

Fig. 1 presents the dynamics of HR during incremental bicycle ergometry test. B sub-group HR during incremental test increased statistically significantly more than in A sub-group, p<0.05. A subgroup reach greater workload (300W). Before test JT/RR ratio in A sub-group was 0.35±0.007; in B sub-group – 0.37±0.008; when reach 200 W workload JT/RR ratio in B sub-group become 0.48±0.008, in A sub-group this JT/RR interval meaning was reached at 250 W workload (p<0.05).

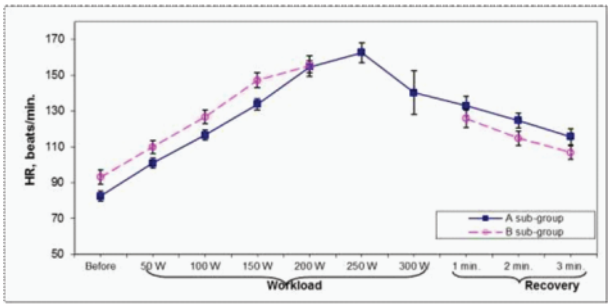

Fig. 1. Dynamics of HR during during incremental test.
Slika 1. Vrijednosti FS za vrijeme progresivnog testa

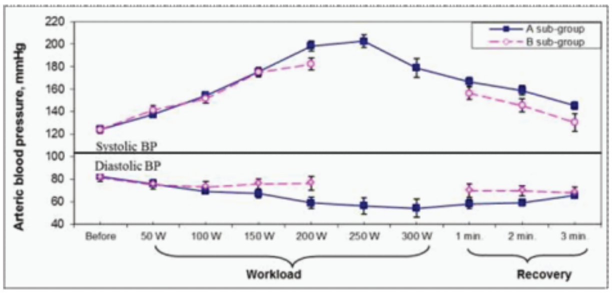

Fig. 2. Dynamics of arterial blood pressure during incremental test.
Slika 2. Vrijednosti arterijskog krvnog tlaka za vrijeme progresivnog testa

Differences between sub-groups A and B in the dynamics of diastolic blood pressure during load are evident (Fig. 2). In case of sub-group B, at the beginning of load, diastolic blood pressure decreased (100 W – 73.3±4 mmHg), and this is typical for all subjects (sympathetic activity together with metabolites of muscle cells cause dilatation phenomenon in the functional periphery), a normal physiological response. Later, it starts increasing (upon achieving the load of 200 W – 76.5±5,3 mmHg), and decreases again after the load, although not so quickly. The difference is statistically significant, $p<0.05$.

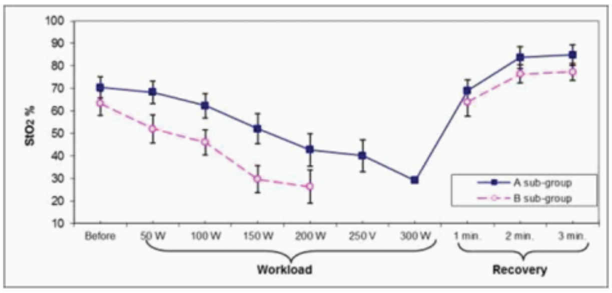

Fig. 3. Dynamics of StO_2 during incremental test.
Slika 3. Vrijednosti StO_2 vrijeme progresivnog testa

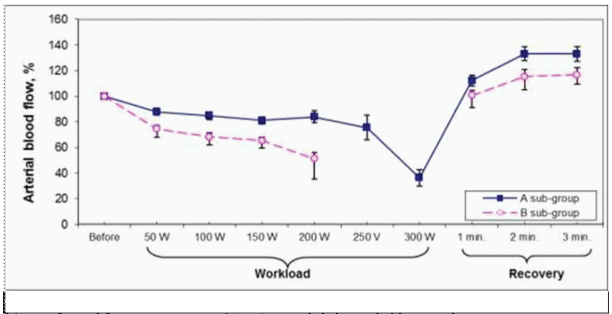

Fig. 4. Dynamics of arterial blood flow during incremental test.
Slika 4. Vrijednosti arterijskog protoka za vrijeme progresivnog testa

Fig. 3 presents StO_2 dymanics during incremental test. The nature of changes in StO_2 is close related to effect of vascular vasodilatation. Oxygen saturation was higher and in all workload oxygen desaturation in A sub-group was slow, $p<0.05$.

Blood flow during incremental test showed (Fig. 4) that blood flow decreased statistically significantly faster in weaker (B) sub-group. The greatest arterial blood flow decrease in A sub-group was established at 300 W workload, this decrease was 63.7±6.4% from 100%.

The results obtained in the study showed an increasing changing HR and the StO_2, arterial blood flow decreased during the incremental increase in workload significantly with every next step of workload in both athletes groups. The characteristics of changes in StO_2 were closely related to the effects of vascular vasodilatation. When the workload increased much and serious ischemic episodes in cardiac muscle occurred the curve of changes of StO_2 depended on the functional prepardness of the participant of the study. Assessments of cardiovascular function complemented by data obtained by NIRS provides the ability assess the cardiovascular changes during exercising more precisely, i. e. to assess the links between central and peripheral changes in cardiovascular system. As show Murias et al. (2013) studies results indicate that systemic blood flow and thus O_2 delivery does not reflect the profile of blood flow changes at the level of the microvasculature. As evidenced by other researchers (Burnley, Jones, 2007), assessment of changes in active muscles shows the effects of peripheral arterial vasodilatation or vasoconstriction. Research, carried out by scientists (Clifford, 2007; Schulz E, Münzel, 2011), while assessing the changes in features of muscle blood flow during veloergometric load, revealed that as intensity of physical load increases up to the limit, peripheral arterial vasodilatation becomes apparent, and the blood flow in the calf of the leg becomes significantly more intensified, while performing the last, subjectively very difficult stages of load. This shows the limit of increase of heart muscle functioning capacity and activation of compensatory mechanisms, respectively. Harms et al. (1997) suggesting that exercise capacity and locomotory muscle blood flow is reduced, that maneuvers redistributing part of the blood flow away from the locomotory muscles reduces exercise capacity if the respiratory muscles are loaded. 2003 Gonzalez-Alonso and Calbet reached a similar conclusion. In their study, subjects performed constant intensity exercise to exhaustion under normothermic and hyperthermic conditions. In both conditions, fatigue was preceded by a reduction of cardiac output and leg blood flow. Although O_2 delivery is a function of locomotor muscle blood flow, this does not exclude the possibility that other mechanisms marginally contribute to achieve V O_{2max} in normoxia, (Dempsey, Wagner, 1999; Nielsen, 2003), a diffusional limitation between the capillaries and the mitochondria of the active muscle fibers (Roca, 1989), and lower O_2 extraction capacity in some muscles (Calbet at al. 2005) blood flow. During whole body upright exercise the combined maximal muscular vascular conductances of the limbs outweighs the pumping capacity of the heart in humans, meaning that oxygen saturation is limited by O_2 delivery. In case of our research, when physical load, increased in stages, becomes close to the limit values of subject, arterial muscle blood flow and oxygen saturation decreases during physical load. Higher blood flow of muscles, working during physical load, is influenced by increased systolic and cardiac output, as well as arterial blood pressure. In case of increasing a physical load in steps for non-athletes, systolic volume increases at the beginning of load, however, as the load increases, especially, when performing the load with the greatest efforts, systolic volume decreases. Changes in arterial blood pressure indirectly show the response of heart and other cardiovascular structural components to physical load (Fagard, 1997; Sagiv et al., 1999). According to Moore et al. (2008), the values of oxygen consumption, cardiovascular functional parameters during veloergometric load depend on the pedaling speed. While some authors have found that in case of faster speed, but the same power, heart rate is higher (Moore et al., 2008), others have not noticed any significant impact of pedaling speed on heart rate during load of different or constant intensity (Chavarren, Calbet, 1999; Lepers et al., 2001). It is believed that at higher pedaling speed the increased demand of oxygen increases the cardiac output, which in turn is increased by higher systolic blood volume, increased due to higher venous blood supply to heart, i.e., better "muscle pump" effect. However, in case of our research, pedaling speed had no influence on cardiovascular functional values, since all subjects used the same pedaling speed, i.e., 60 rev. / min. Poškaitis et al. (2007) determined that while performing the subjectively difficult (last) stages of load with veloergometer, the decrease of oxygen saturation in muscles of some subjects is replaced by reverse process – a gradual increase of oxygen saturation starts taking place. This shows the limit of increase of heart muscle functioning capacity and involvement of compensatory mechanisms in this process, respectively. As intensity of physical load increases to maximum, the rise of oxygen saturation curve coincides with increasing signs of ischemic myocardium.

CONCLUSION

During stepwise incremental workload to failure, the differences of functional preparedness can be observed only during the initial stages of exercising (dosed workload), but when the load became subjectively heavy, i. e. at the last testing stages (maximum workload), differences between central cardiovascular functional parameters were not found, and in contrast, differences between peripheral cardiovascular functional parameters were more observable oncoming to the maximum load: increasing workload decreased the blood flow and oxygen saturation of active muscle.

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