CARDIOVASCULAR FUNCTION AND SURAL ARTERIAL CIRCULATION DURING THE BICYCLE ERGOMETRIC TEST OF SPRINT AND ENDURANCE RUNNERS

by

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We tested the hypothesis that effects of different training programs reflects in the relation of changes of arterial circulation and cardiovascular function. The subjects of this study were 17 sprinters and 13 long distance runners. An incremental bicycle ergometer test was used. The subject underwent a increase in workload and they exercised to a predetermined goal (submaximal heart rate) unless distressing cardiovascular symptoms supervened. A computerized 12-lead ECG analysis system "Kaunas-Load"was employed for ECG recording and analysis. The intensity of sural arterial circulation was registered by Whitney plethysmograph. Results: The sural arterial circulation during the incremental exercise test undergoes the bi-phasic change: slow augmentation and steep increase. The endurance group features a more extensive slow augmentation phases (5,58±0,24 minutes) and greater peak values of blood flow (80.88±6.17 ml/min/100 cm^3) when compared with the sprint cohort (4,73±0,29 minutes and 69.82±5.66ml/min/100 cm^3 respectively). ST-segment depression at the end of an exhausting workout proceeds the rapid increase in sural arterial circulation. Rapid vasodilation is one of the ways to make up for the limited cardiac capacity. In conclusion, different effects of training on cardiovascular system reflects in the values of changes of arterial circulation and cardiovascular function. The intensity of sural arterial circulation during exercise has to be assessed along with the functional capacity of cardiovascular system.

Key words: cardiovascular system, muscle blood flow, exercise test

Introduction

Endurance and high-intensity sprint training have been shown to alter skeletal muscle blood flow and factors that govern muscle perfusion under

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various conditions [Delp, 1998; Delp and Laughlin, 19982]. The blood flow to muscles is generally proportional to their metabolic activity [Knight et al., 1996; Bangsbo and Hellsten , 1998; Hughson and Tschakovsky, 1999]. The major portion of the exercise cardiac outputs is diverted to the working muscles [Saltin et al., 1998; Delp, 1998; Joyner and Proctor, 1999]. Potential mechanisms through which muscle perfusion is altered during prolonged or incremental exercise are not fully understood [Bangsbo and Hellsten, 1998; Joyner and Proctor, 1999; Shoemaker and Hughson, 1999]. At the onset of exercise or at cardiovascular system adapts with a series integrated response to met the metabolic demands of the exercising muscles. Regulatory mechanisms of the systemic blood circulation is oriented to sustain a gradient of pressure, necessary to insure needed blood circulation intensity in working muscles. This happens in the combination of heart work indexes and changes of peripheral resistance [Hughson and Tschakovsky, 1999; Joyner and Proctor, 1999; Shoemaker and Hughson, 1999]. Why this the regional and central factors can‘t be separated and both must be taken into account.

We tested the hypothesis that effects of different training programs reflects in the relation of changes of arterial circulation and cardiovascular function. The objective of this study was to find out the relation in changes of cardiac functional capacity and sural arterial circulation during the incremental exercise test in endurance and sprint cohorts.

Material and methods

An incremental bicycle ergometer test was used. The subjects underwent a 50W increase in workload every 60 seconds (60revoliutions/min) and they exercised to a predetermined goal (submaximal heart rate) unless distressing cardiovascular symptoms supervened. A computerized ECG analysis system “Kaunas-Load”, developed at the Kaunas Medical University Institute of Cardiology, was employed for 12 lead ECG recording and analysis. ST-segment response (segment depression) to exercise was used to assess the functional capacity of cardiovascular system [Vainoras, 1996; Jernberg et al., 1999; Yazigi et al., 1999].

The intensity of sural arterial circulation was registered by Whitney plethysmograph joined through Winstone bridge. The plethysmographic curve was recorded by an IBM personal computer, and a curve analysis program "Adrec" was used for its interpretation. The amount of sural blood flow was estimated using the method based on the acting mechanism of the muscle pump [Stoida et al., 1998]. The patient would cease exercising for 4 seconds (stopped, and relaxed leg muscles). By this method, the velocity with which the calf the calf was increasing in volume was reflecting the arterial blood flow rate – the extent of arterial vasodilation at a given moment of testing [Stoida et al., 1998].

The subjects of this study were 17 sprinters, aged 20,9±1,15, body mass index 22,3 ± 0,32, and 13 long distance runners, aged 21,3±1,31, body mass index 21,2 ± 0,49.

To make the comparison in changes of cardiovascular function and sural arterial circulation easy we assessed the coefficient of correlation between normalized changes of registered indices. The normalization of changes during each step of workload was performed according to the maximum values registered during the experiment.

Results

At the beginning of the workload the sural blood flow intensified slowly but after having reached a certain intensity of exercise the blood flow rate rapidly increased up to the maximum values. We have ascertained such nature of hemodynamic changes during the workload for all the cases but the moment of the steep increase of blood flow was different and individual. Therefore analysing the obtained results we differentiated a slow augmentation and steep increase of sural arterial circulation and assessed the moment of time when the velocity of increase of blood flow rate elevated rapidly (Fig.1).

Augmentation of blood flow rate at the beginning and during the main part of the workload in the sprint group was slower than in endurance group but the moment of sudden change to steep increase of arterial circulation occurred earlier, i.e. after 5,58 ± 0,24 minutes since the start of exercising. In the endurance group this sudden change happened in 4,73±0,29 minutes of the workload (the difference between the cohort was statistically significant, p< 0.05). The endurance group in comparison to the sprint group features a more extensive slow augmentation phase and a sudden change from slow augmentation to steep increase occurred in the presence of greater blood flow values: 43,87±4,94ml/min/100 cm^3 in the endurance group and 32,26±2,34ml/min/100 cm^3 in the sprint group.

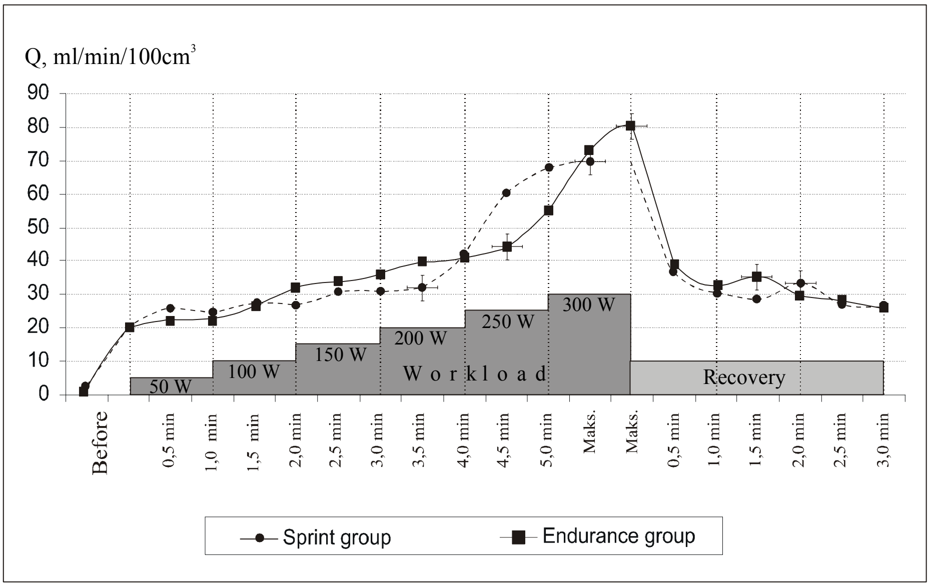

Fig. 1. Sural arterial ciculation during exercise test

The obtained results have shown two other peculiarities in sural arterial circulation. First, the greater amount of blood flow i.e. the peak values was registered for the representatives of the endurance group (on average 80.88 ±6.17 ml/min/100 cm^3) than for representatives of the sprint group (69.82±5.66ml/min/100 cm^3). Second, during the recovery period there was a short in duration and relatively small increase of blood flow occurring earlier in the endurance group, i.e. after 1.76±0.09 minutes. In the sprint group this increase happened on average 2.09±0.08 minutes after the end of exercising ($p<0,05$).

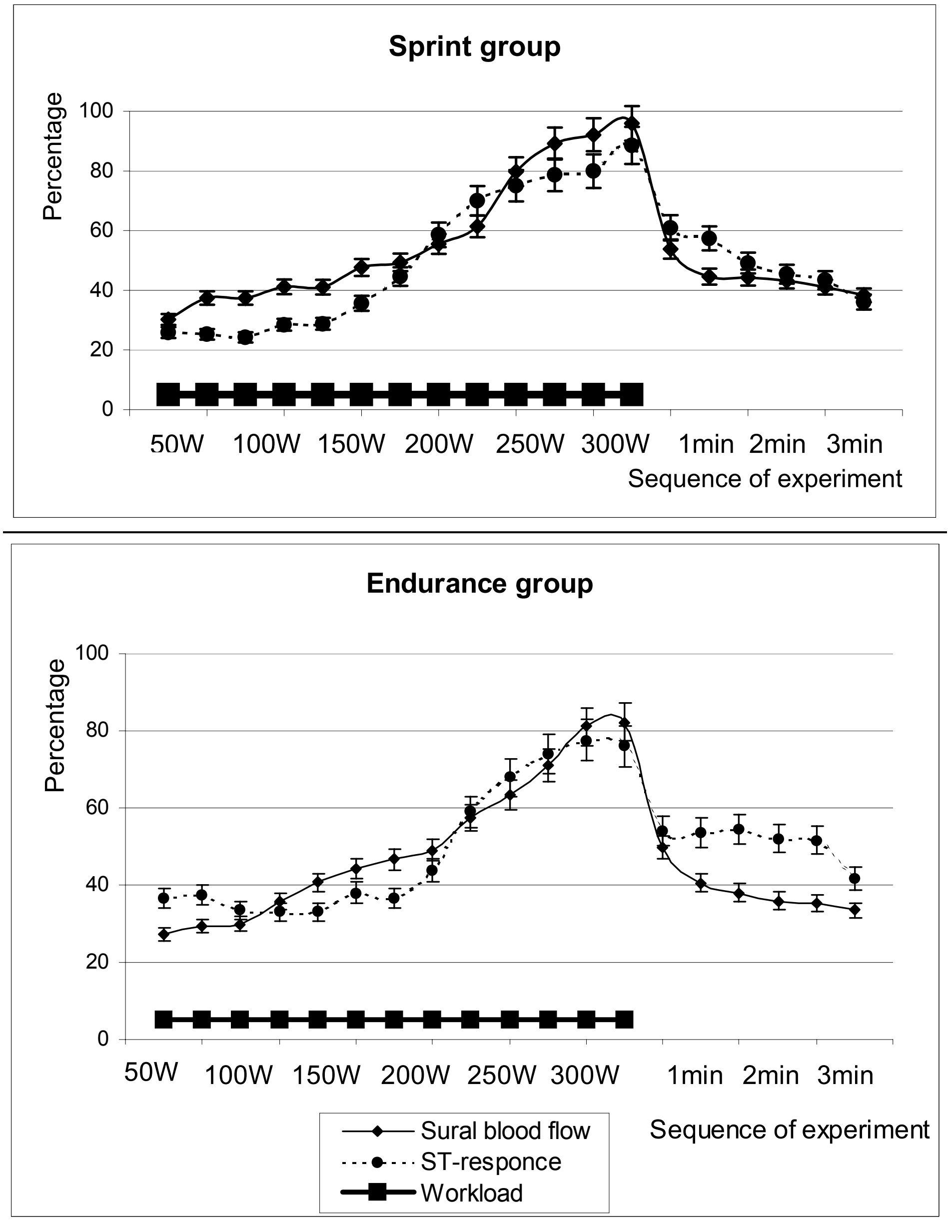

Fig. 2. The dynamics of normalized values of ST-segment depression and sural arterial circulation

The dynamics of ST-segment response to exercise test was similar to the hemodynamic changes in the calf. When the load increased up to the exhausting level and the cardiac capacity became restricted, i.e. the ST-segment depression increased rapidly, the second phase, i.e. steep increase of arterial vasodilation began. The comparison of normalized values has shown that the changes in ST-segment depression started first which was followed the steep increase of peripheral hemodynamics (Fig. 2). When the performance of the workload became hard and close to the personal physical limits, i.e.250-300W, we have found a 30 s delaying statistically significant correlation (r=0.586) between the changes in ST-segment depression and the changes of the blood flow intensity.

Discussion

The bicycle ergometric workload which was used in our investigation engaged a large muscle mass so the functional capacity of the cardiovascular system plays an important role [Saltin et al., 1998; Yazigi et al., 1998]. It is the capacity of “resistance vessels” to alter dramatically their internal diameter that provides a rapid and effective means for regulating blood flow through the peripheral vasculature [Saltin et al., 1998; Hughson and Tschakovsky, 1999]. The obtained results have shown two important facts. First, the sural arterial circulation during the incremental exercise undergoes the bi-phasic change: slow augmentation and steep increase. Second, the changes in ST-segment depression started first which was followed the steep increase of peripheral hemodynamics. These two peculiarities was observed in both cohorts. The different effects of training on cardiovascular system reflects only in the values of changes in arterial circulation and cardiovascular function. The endurance group features a more extensive slow augmentation phases and greater peak values of blood flow when compared with the sprint cohort.

An intense arterial circulation in active muscles is associated with good condition for delivery of oxygen and metabolic substrates to, as well as removal of metabolic by-products and heat from actively contracting muscles. It was shown in many studies [Knight et al., 1996; Poderys, 1998; Delp, 1998; Saltin et al., 1998]. The second fact, i.e. ST-segment depression proceeds the rapid increase in sural arterial circulation indicates that such response of peripheral vessels is a compensatory mechanism at the onset of myocardial ischemia. Prognostic importance of ischemic episodes detected by ST-segment monitoring with continuous 12–lead ECG during exercise test was shown in many investigations [Vainoras, 1996; Yazigi et al., 1998; Jernberg et al., 1999; Joyner and Proctor, 1999]. The transient ST-segment depression during the incremental exercise indicates the ischemic processes of functional nature, i.e. a limited cardiac functional capacity [Vainoras, 1996]. This ST-segment response was characteristic in all cases and proceeds the rapid increase in sural arterial circulation. Thus the dynamics of sural arterial circulation during exercise has to be assessed along with the functional capacity of cardiovascular system.

A delayed short in duration and relatively small increase in arterial circulation in the period of recovery and the differences in time between the groups may be explained by the removal of lactate from muscle tissue to blood. It was not our aim to study the peculiarities of hemodynamic in the period of recovery. This is an important problem[Bangsbo and Hellsten, 1998] and the cause of elevated blood flow in the recovery period from exercise remains to be assessed.

In conclusion, different effects of training on cardiovascular system reflects in the values of changes of arterial circulation and cardiovascular function. The dynamics of sural arterial circulation during exercise has to be assessed along with the functional capacity of cardiovascular system.

REFERENCES

Bangsbo J., Y. Hellsten (1998) Muscle blood flow and oxygen uptake in recovery from exercise. *Acta Physiol. Scand.* 162(3):305-312

Delp M.D. (1998) Differential effects of training on the control of skeletal muscle perfusion. *Med. Sci. Sports Exerc*. 30(3):361-374

Delp M.D., MH Laughlin (1998) Regulation of skeletal muscle perfusion during exercise. *Acta Physiol. Scand*. 1998 162(3):411-419

Hughson R.L., M.E. Tschakovsky (1999) Cardiovascular dynamics at the onset of exercise. *Med. Sci. Sports Exerc*. 31(7):1005-1010

Joyner M.J., D.N. Proctor (1999) Muscle blood flow during exercise: the limits of reductionism. *Med. Sci. Sports Exerc.* 31(7):1036-1040

Jernberg T., B. Lindahl, L. Wallentin (1999) ST-segment monitoring with continuous 12-lead ECG improves early risk stratification in patients with chest pain and ECG nondiagnostic of acute myocardial infarction. *J. Am. Coll. Cardiol.* 34(5):1413-1419

Knight D.R., D.C. Poole, M.C. Hogan, D.E. Bebout, P.D. Wagner (1996) Effect of inspired O2 concentration on leg lactate release during incremental exercise. *J. Appl. Physiol.* 81(1):246-251

Poderys J. (1998) Influence of the short term preliminary occlusion on the dynamics of arterial blood flow and working capacity of the calf muscles. *J. Educ. Phys. Training Sport* 1:49 – 57.

Saltin B., G. Radegran, M.D. Koskolou, R.C. Roach (1998) Skeletal muscle blood flow in humans and its regulation during exercise. *Acta Physiol. Scand.* 162(3):421-436

Shoemaker J.K., R.L. Hughson (1999) Adaptation of blood flow during the rest to work transition in humans. *Med. Sci. Sports Exerc.* 31(7):1019-1026

Stoida Iu.M., Vinogradova O.L., Golovachev A.I. (1998) Effect of 3-day immersion on calf blood flow during physical loading test. *Aviakosm. Ekolog. Med*.32(2):24-27 (in Russian, English abstract).

Yazigi A., F. Richa, S. Gebara, F. Haddad, G. Hayek, M.C. Antakly (1998) Prognostic importance of automated ST-segment monitoring after coronary artery bypass graft surgery *Acta Anaesthesiol. Scand.* 42(5):532-535

Vainoras A. (1996) Investigation of the heart repolariztion process during rest and bicycle ergometry (100-lead and standard 12-lead ECG data) Synopsis of a D.Sc.habil.thesis Kaunas