THE EFFECT OF SUBMAXIMAL EXERCISE ON BLOOD CREATININE, UREA, TOTAL PROTEIN AND URIC ACID LEVELS OF TRAINED AND UNTRAINED SUBJECTS

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ABSTRACT

There are numerous studies about exercise-induced sports hematuria, proteinuria, acute renal failure following a marathon (Steward, Posen, 1980; Poortmans et al., 2001; Ayca et al., 2006). But studies investigating the effects of exercise on blood indicators of renal function are quite few.

The aim of this study was to investigate the effects of submaximal veloergometric exercise on very important biochemical indicators of renal function — level nitrogen compounds in the blood. We investigated concentration of creatinine, urea, total protein and uric acid in venous blood samples before and after submaximal veloergometric exercise. Those nitrogen compounds were studied in three groups of subjects.

The study was performed with 10 trained (Group 1), 10 untrained subjects (Group 2) and 10 subjects with I^o hipertensive status (Group 3). The age range was 20.5—21.3 years, weight — 71.8—77.3 kg, height — 180—177 cm. All subjects voluntered to participate in the study after providing written informed consent. The study was approved in accordance with the Declaration of Helsinki. Blood samples were collected before and after the submaximal veloergometric test into vacumtrainer tubes. Concentrations of creatinine, urea, total protein and uric acid in the serum were determined using Technicon Auto Analyzer ADVIA 1650 system.

All data were reported as mean ± standard deviation (SD) unless otherwise specified, and statistical significance was recognized when $p \leq 0.05$.

No statistically significant difference was observed between pre- and post exercise blood creatinine, urea, total protein and uric acid mean levels of all group subjects. A marked exercise induced increase in blood creatinine and total protein concentrations was observed when the results of trained and untrained participants' parameter differences were compared after the exercise.

A significant ($p < 0.05$) exercise-induced increase in blood urea and total protein concentration was observed when the mean values of Group 1 and Group 2 before the exercise and parameters after the exercise were compared.

When blood creatinine, urea, total protein and uric acid levels were compared separately for the participants, it was observed that seven persons in Group 1 and three persons in Group 2 showed a marked exercise-induced increase in the blood nitrogen compounds level.

Research results suggest that 1) the testing exercise-induced statistically insignificant ($p > 0.05$) increases in the blood parameters of nitrogen compounds (creatinine, urea, total protein and uric acid) could be due to the common phenomenon of the physical stress and catecholamine effects, 2) postexercise changes of blood nitrogen compounds were significant ($p < 0.05$) when the results of Group 1 with Group 2 participants were compared. The significant differences in metabolic responce in Group 1 and Group 2 participants probably reflect differences in work volume and intensity, and 3) further studies are needed to be performed on more subjects to evaluate exercise-specific effects on postexercise changes of blood nitrogen compounds in athletes and nonathletes.

Keywords: *blood, creatinine, urea, total protein, uric acid.*

INTRODUCTION

Testing in sport science is important for many reasons. The main purpose of testing is to establish the weakness of athletes and other individuals (Gore, 2000). Biochemical parameters and cardiac function is assessed according to a variety of indicators, including blood pressure response to exercise. Blood pressure is of particular importance, because hypertension is associated with an increased cardiac function and renal reaction. Elevated systolic or diastolic blood pressure is associated with risk of developing congestive heart function and kidney failure. The risk is nearly doubled when blood pressure is greater than 140 / 90 mmHg. Essential hypertension is the result of functional disturbances in blood volume, cardiac output, total peripheral resistance and regulation of kidney function (Ibsen et al., 2004, 2005). Many studies have reported an inverse relationship between the level of physical activity, fatigue and blood pressure (Curtis, Russel, 1997).

Recently it has been recognized (Ehrman et al., 2003) that exercise-induced minor renal dysfunction (i. e. reduced glomerular filtration rate) particularly in the trained subjects, is unduly understimated by relying only on the serume creatinine and urea values as the index of renal function.

The serum creatinine concentration depends not only on the glomerular filtration rate, but also on a number of confounding factors, particularly muscle mass, consumption of cooked meat, tubular secretion of creatinine and physical exercise load.

Nitrogen and its compounds and metabolites (creatinine, urea) are an important metabolic intermediate involved in many reactions within the body (Poortmans, Vanderstraeten, 1994). Nitrogen intermediate metabolites concentrations in the blood changed during to submaximal intensity exercise (e. g. up to 50% $_{max}$) (Bakonska-Pacon, Borkowski, 2003). Appreciable increases in creatinine, urea, total protein concentrations in the blood become evident at exercise intensities in the range of 70—75% $_{max}$. Large increases, found in athletes, probably reflect a greater mass of muscle, that depletes ATP to greater extent than typically found in untrained persons.

Blood nitrogen intermediate metabolites concentrations in I^o hypertensive persons was greater than in trained and untrained persons (Terjung, Tullson, 1992). On the other hand, exercise can lead to increased accumulation of nitrogen intermediate metabolites in the blood if exercise is sufficiently intense and / or because of disordered renal function. Thus the observed blood nitrogen metabolites concentrations can vary depending on the exercise conditions (Poortmans et al., 2001). A clear dissociation between blood creatinine, urea and total protein concentrations can be easily demonstrated under conditions of their production and / or clearance from the blood in urine (Zambraski, 1990). In contrast to the defects described above, patients with I^o type hypertension show an appreciable blood nitrogen metabolites accumulation with exercise, but little if any urea production. In addition, high levels of to uric acid (purine metabolite) are detected in blood when intensive adenine nucleotide degradation is observed, but not in all subjects. These responses are consonant with energy imbalance within the active muscle and are generally consistent with other known features of the disability energy metabolism (Terjung and Tullson, 1992).

Haemodynamic changes in the kidney take place during the physical effort — the blood pressure rises and its flow through the kidney falls (Poortmans, Vanderstraeten, 1994). These changes lead to disorders in the glomerular filtration and in mechanisms of the reabsorbtion which as a consequence influence the after effort blood content. The growth or the fall of the nitrogen compounds concentrations in the blood might be the reflection of physiological or pathological changes in the kidney. The estimated urea production rate during exercise suggests increased protein catabolism (Jansen et al., 1989; Portmans et al., 2001). The prolonged heavy exercise is accompanied by increased protein catabolism and changes in the plasma nitrogen compounds concentrations, similar to those observed during starvation, but differing from those seen at heavy exercise of less than 2 hours duration or prolonged exercise of moderate intensity (Refsum et al., cit. by Poortmans, Vanderstraeten, 1994).

There are numerous studies about exercise-induced sports proteinemia, hematuria, proteinuria, acute renal failure following marathon (Steward, Posen, 1980; Poortmans et al., 2001; Ayca et al., 2006). But studies investigating the effects of submaximal exercise on blood nitrogen indicators of renal function are quite few.

The aim of this study was to investigate the effects of submaximal veloergometric exercise on very important biochemical indicators of renal function — level nitrogen compounds (creatinine, urea, total protein) and uric acid (purine metabolite) in the blood.

MATERIALS AND METHODS

Subjects. The study was performed with 10 trained (Group 1), 10 untrained (Group 2) participants and 10 subjects with I^o hypertensive status (Group 3). The age range was 20.5—21.3 years, weight — 71.8—77.3 kg, height — 180—177 cm.

Ten normotensive, healthy subjects of Group 1 were students, soccer players. The training of soc-

Table 1. **Physical characteristics of participants in three groups (trained, untrained and I° hypertensive subjects)**

Group	N	Age, years	Weight, kg	Height, cm	BMI, kg / m²	Blood pressure	
						Systolic, mmHg	Diastolic, mmHg
Group 1 Trained	10	20.5 ± 0.53	72.42 ± 4.94	1.81 ± 0.04	22.1 ± 1.08	117.5 ± 3.1	83.10 ± 2.24
Group 2 Untrained	10	21.3 ± 0.82	71.8 ± 4.13	1.77 ± 0.07	22.94 ± 1.62	120.0 ± 2.8	90.0 ± 2.18
Group 3 I° hypertensive subjects	10	20.7 ± 0.67	77.3 ± 7.56	1.80 ± 0.04	23.82 ± 2.35	158 ± 3.5	99 ± 3.10

Table 2. **Nitrogen compounds concentrations in the blood of trained, untrained and I° hypertensive subjects before and after testing exercise (mean ± standard error)**

Group	Before exercise				After exercise			
	Creatinine, µmol / l	Urea, mmol / l	Protein, g / l	Uric acid, µmol / l	Creatinine, µmol / l	Urea, mmol / l	Protein, g / l	Uric acid, µmol / l
Group 1	96.70 ± 8.17	6.18 ± 0.66	71.66 ± 5.33	192.40 ± 38.59	116.80 ± 5.25	7.48 ± 0.71	78.25 ± 5.05	220.60 ± 38.30
Group 2	96.60 ± 9.69	5.36 ± 0.95	69.41 ± 4.02	201.60 ± 79.29	100.10 ± 9.72	5.26 ± 0.65	71.21 ± 4.27	217.40 ± 55.61
Group 3	103.50 ± 10.70	6.36 ± 1.37	78.62 ± 2.84	217.40 ± 55.61	—	—	—	—

cer players during the last week before the testing consisted of high-intensity training exercise (for 90 min) 2 days a week and moderate — intensity training once a week.

The subjects of Group 2 (n = 10) were untrained students of Kaunas University of Medicine, who were involved in irregular physical activity.

The subjects of Group 3 (n = 10) were untrained young soldiers with symptoms of primary arterial hypertension.

Experimental protocols. Half an hour before exercise the antropometric values and blood pressure were measured. The blood was taken from the antecubital vein. Concentrations of creatinine, urea, total protein and uric acid in the blood serum were determined by using Technicon Auto Analyzer ADVIA 1650 system.

Testing Procedures. The incremental test was performed on a cycle ergometer (Monarc). The load consisted of pedaling at 60 rpm / min. The participants were instructed and sat quietly for one minute on the ergometer before starting the exercise at 50 W. The load was increased by 50 W every minute until maximal voluntary exhaustion was reached. Power and stroke rates were delivered continuously by computer display on the stacionary cycle ergometer. The test was designed to reach the maximum in approximately 7 minutes (mean load of 350 ± 25 W) with the subjects of Group 1 and 5 minutes (250 ± 13 W) with the subjects of Group 2.

After the testing exercise the blood was also taken from antecubital vein for biochemical analysis.

The results were reported as the mean ± standard error of the mean, and statistical significance was recognized when $p \leq 0.05$.

The physical characteristics of the participants from all the three groups were shown in Table 1.

RESULTS

The blood nitrogen compounds mean results of trained, untrained and I° hypertensive subjects were shown in Table 2.

As the results presented in Table 2 suggest, the pre-exercise blood concentrations of creatinine, urea, total protein and uric acid were markedly higher in subjects with I° hypertension status (Group 3) compared to trained and untrained participants (Group 1 and Group 2), but concentrations of those blood parameters were higher in trained subjects (Group 1) compared with parameters of untrained subjects (Group 2).

The postexercise blood nitrogen compounds levels of trained participants (Group 1) were higher than the preexercise levels, and postexercise levels of trained subjects were markedly higher ($p < 0.05$) than those of untrained (Group 2). However, before and after the exercise the increase of results in Group 1 and Group 2 was not statistically significant ($p > 0.05$).

No statistically significant differences were observed between pre- and post-exercise blood creatinine, urea, total protein and uric acid levels comparing the mean results of the subjects in all groups (Table 2). But the results, presented in Table 3, show a significant exercise induced increase in

Table 3. **Comparison of significant differences in mean values of blood nitrogen compounds investigated after the exercise in subjects of Group 1 and Group 2**

Parameters	Stjudent *t* test	Significance of differences	Differences in mean results	Standard error
Creatinine	4.780108	0.00015	16.7	3.493645
Urea	7.312767	0.000000856	2.22	0.303579
Total protein	3.364807	0.00345	7.04	2.092245
Uric acid	0.581392	0.568186	16.1	27.69214

Table 4. **Comparison of significant differences in mean results of blood nitrogen compounds before and after the exercise in subjects of Group 1 and Group 2**

Parameters	Stjudent *t* test	Significance of differences	Differences in mean results	Standard error
Creatinine	6.78069	0.00000237	16.6	2.448129
Urea	3.85754	0.001154	1.401	0.363185
Total protein	4.420618	0.00033	4.79	1.083559
Uric acid	5.442993	0.000036	25.3	4.648178

blood creatinine and total protein levels were observed when we compared the results of trained and untrained participants only after the exercise.

Table 4 shows the significant ($p < 0.05$) differences between exercise-induced increase in blood concentration of creatinine, urea, total protein and uric acid when we compared the results before the exercise with the values of those parameters after the exercise.

Our data showed that the results of blood nitrogen compounds before and after the exercise in Group 1 and Group 2 did not significantly differ comparing the differences in blood nitrogen compounds mean concentrations, but trained participants demonstrated markedly higher values ($p < 0.05$) in post-testing exercises compared to the values of untrained participants. The differences in the levels of creatinine, urea, total protein and uric acid between the groups became larger when we compared the exercise intensity and load (350 ± 25 W in Group 1 and 250 ± 13 W in Group 2). Although neither nitrogen compounds nor uric acid (purine metabolite) showed significant changes after the exercise, the more increased level of creatinine, urea and total protein in trained subjects compared with untrained participants' results could be related to greater total load of work in Group 1.

DISCUSSION

The hard exercise load and physical stress can induce muscle injury, kidney and liver damage (Cerny, Burton, 2001). Muscle injury associated with unaccustomed forceful eccentric contractions, which result in large efflux of protein into the blood, has caused kidney and liver failure (Cerny, Burton, 2001; Ehrman et al., 2003). Diagnosis of renal failure is typically made by determination of levels of serum creatinine, blood urea and other nitrogen compounds through blood test (Ehrman et al., 2003).

Physical exercise frequently induced acute hypertension and renal dysfunction is a high risk combination of overreaching and overtraining. An exercise which provides appropriate overload through manipulation of exercise intensity, duration and frequency becomes sufficient stress.

Physical exercise frequently is accompanied by increased protein catabolism and changes in the blood nitrogen compounds concentrations (Jansen et al., 1989; Hubner-Wozniak et al., 1996). It seems well established that proteins do not serve as a major fuel for energy production during physical exercise (Terjung, Tullson, 1992).

However, it has been clearly documented that strenuous exercise, in particular of prolonged duration, is accompanied by enhanced protein catabolism (Jansen et al., 1989) and several studies have been dedicated to increase the understanding of the significance of the nitrogen compounds metabolism during various types of exercise (Ayca et al., 2006).

Our data show that the comparison of pre-exercise and post-exercise values of blood nitrogen compounds concentrations in the participants of Group 1, 2 and 3 was accompanied by a marked increase in creatinine and urea concentrations, a moderate increase in total proteins and slight increase in uric acid levels. Together with the marked changes in the plasma nitrogen compounds pattern during exercise they add further support to the contention that enhanced protein and nitrogen compounds metabolism constitute an integral part of the metabolic response to exercise. The differences in metabolic response in the participants of Group 1 and Group 2 probably reflect differences in work intensity and volume.

The deviant behaviour of the uric acid, showing unchanged or slight increased plasma concentrations at the end of exercise, are probably due to specific characteristics in their metabolism and bioenergy (Green, Fraser, 1988). Neither creatinine, nor urea are metabolized in muscles and their high levels in plasma and strikingly low concentrations in the postexercise urine show that these nitrogen compounds in particular are subject to the reduction of the renal excretory functions associated with heavy exercise (Poortmans et al., 2001).

Kidneys are highly active, because of the activity of epithelial cells of the proximal tubule, but decreased glomerular permeability or increased tubular reabsorption may increase the levels of blood nitrogen compounds. Therefore, blood nitrogen compounds is of great clinical interest as a marker for several renal disease (Poortmans, Vanderstraeten, 1994). When renal function changes, total protein and nitrogen compounds levels in the blood increase. Increased blood nitrogen compounds levels can be considered the indicator of proximal tubule function alteration (Ayca et al., 2006; Jansen et al., 1989). Postexercise increases were also detected in blood creatinine, urea, total protein and uric acid levels, while no change or decrease was observed in the clearance parameters. It is also known that the catecholamines released from the renal nerves can stimulate renin secretion by a β-adrenergic effect. This effect will enhance the responses of the renin-angiotensine system as reported by several authors during exercise (Zambraski, 1990). This observation rules out the potential action of catecholamines through the renin-angiotensin system and in the exercise induced hypertension of trained participants and subjects with I° hypertension.

As our data showed there were no significant differences in the concentration of blood creatinine, urea, total protein and uric acid in trained, untrained participants and the participants with I° hypertensive status before the testing exercise. On the other hand, individual changes of nitrogen compounds in four trained participants, three untrained participants and six participants in the group of I° hypertension status occured as a moderate increase of those parameters before exercise and a marked increase after testing exercise in Group 1 and Group 2.

A significant exercise-induced increase in blood creatinine and total protein concentration was observed comparing the differences of trained and untrained participants after the exercise. A significant ($p < 0.05$) exercise-induced increase in blood concentrations of urea and total protein was noticed comparing the values before the exercise and after the exercise.

CONCLUSIONS

1. The testing exercise-induced statistically insignificant ($p > 0.05$) increases in the blood parameters of nitrogen compounds (creatinine, urea, total protein and uric acid) could be due to the common phenomenon of the physical stress and catecholamine effects.
2. Postexercise changes of blood nitrogen compounds were significant ($p < 0.05$) when the results of Group 1 with Group 2 participants were compared. The significant differences in metabolic responce at Group 1 and Group 2 participants probably reflect differences in work volume and intensity.
3. Further studies are needed to be performed on more subjects to evaluate exercise-specific effects on postexercise changes of blood nitrogen compounds in athletes and nonathletes.

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TRENIRUOTŲ IR NETRENIRUOTŲ ASMENŲ KRAUJO KREATININO, ŠLAPALO, BENDROJO BALTYMO IR ŠLAPIMO RŪGŠTIES KONCENTRACIJOS KITIMAS DĖL SUBMAKSIMALAUS FIZINIO KRŪVIO

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SANTRAUKA

Literatūros šaltiniuose yra nemažai straipsnių apie sportininkų hematuriją, proteinuriją, ūmią inkstų pažeidą po maratono bėgimo (Steward, Posen, 1980; Poortmans et al., 2001; Ayca et al., 2006). Tačiau tyrimų, nagrinėjančių kraujo azotinių medžiagų pokytį dėl fizinių krūvių, skelbta nedaug. Šio tyrimo tikslas — išsiaiškinti, kaip submaksimalus veloergometrinis krūvis veikia kraujo azotinių medžiagų rodiklius, labai svarbius inkstų funkcijos pažeidos diagnostikai.

Buvo tiriama 10 aktyviai sportuojančių, 10 nesportuojančių ir 10 tiriamųjų, kurioms nustatyti I^{o} hipertenzijos simptomai. Visi tyrimai atlikti atsižvelgiant į Helsinkio deklaracijos nuorodas. Kreatinino, šlapalo, bendrojo baltymo ir šlapimo rūgšties koncentracija kraujo serume nustatyta naudojant *Technicon Auto Analyzer ADVIA 1650* sistemą. Tyrimo duomenys įvertinti statistinės analizės metodais, apskaičiuojant aritmetinį vidurkį, standartinį nuokrypį, pakliovos intervalą, įvertinant Studento *t* testą, skirtumo patikimumą ir standartinę paklaidą.

Lyginant visų trijų grupių tiriamųjų kreatinino, šlapalo, bendrojo baltymo ir šlapimo rūgšties koncentracijos kraujo serume vidurkių rodiklius, nustatytus prieš fizinį krūvį ir po jo, statistiškai patikimo skirtumo neaptikta. Pastebimas labai didelis kraujo azotinių medžiagų koncentracijos skirtumas po krūvio, lyginant treniruotų ir netreniruotų asmenų tyrimo rezultatų vidurkius.

Nustatytas ryškus ($p < 0,05$) kraujo šlapalo ir bendrojo baltymo koncentracijos vidurkio didėjimo skirtumas, lyginant 1 ir 2-os tiriamųjų grupės rezultatus.

Analizuojant atskirai individualų kraujo serumo azotinių medžiagų koncentracijos kitimą, sukeltą krūvio, nustatyta: po krūvio septynių 1-os grupės ir trijų 2-os grupės tiriamųjų azotinių medžiagų koncentracijos rodikliai smarkiai peržengė fiziologinės normos ribas.

Atlikus tyrimą, galima daryti šias išvadas: 1) po submaksimalaus fizinio krūvio pastebima kraujo azotinių medžiagų koncentracijos didėjimo tendencija ($p > 0,05$) rodo fizinio streso ir katecholaminų poveikį; 2) kraujo azotinių medžiagų koncentracijos po fizinio krūvio statistiškai reikšmingas ($p < 0,05$) skirtumas nustatytas lyginant 1 ir 2-os grupės tiriamųjų rezultatų vidurkius (metabolinio atsako rodiklių reikšmingas skirtumas tarp 1 ir 2-os grupių tiriamųjų galėjo priklausyti nuo darbo apimties ir intensyvumo); 3) norint įvertinti, kaip konkretus fizinis darbas veikia kraujo azotinių komponentų koncentracijos kaitą, reikia atlikti daugiau tyrimų.

Raktažodžiai: kraujas, kreatininas, šlapalas, bendrasis baltymas, šlapimo rūgštis.

Gauta 2007 m. gegužės 15 d.
Received on May 15, 2007

Priimta 2007 m. rugsėjo 19 d.
Accepted on September 19, 2007

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