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Professor **Donald Anthony Neumann** and Professor **Guy Simoneu** from Milwaukee Marquette University, USA, and Professor Dr. Habil. **Povilas Karoblis** from Vilnius Pedagogical University were confered the titles of Doctor Honoris Causa of the Lithuanian Academy of Physical Education at the grand meeting of the Senate of the Lithuanian Academy of Physical Education on May 3, 2007

Professor
Donald Anthony Neumann,
Milwaukee Marquette University

Professor
Guy Simoneu,
Milwaukee Marquette University

Professor Dr. Habil.
Povilas Karoblis,
Vilnius Pedagogical University

Nuoširdžiai sveikiname gerbiamus Jubiliatus gražių sukaktuvių proga. Tegu Jūsų darbai įprasmina visus lūkesčius, o dienos būna šviesios, džiugios, turiningos!

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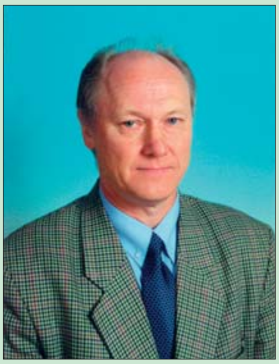

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THE EFFECT OF SUBMAXIMAL EXERCISE ON BLOOD CREATININE, UREA, TOTAL PROTEIN AND URIC ACID LEVELS OF TRAINED AND UNTRAINED SUBJECTS

Alina Gailiūnienė[1], Arvydas Stasiulis[1], Jolanta Michailovienė[1, 2]
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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° 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.

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PHYSICAL FITNESS CHANGES IN GIRLS FROM THE 11TH GRADES PROMOTING THEIR PHYSICAL SELF-DEVELOPMENT AND TRAINING THEIR LEAST DEVELOPED PHYSICAL QUALITIES

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ABSTRACT

The aim of the research was to determine the changes in physical fitness of girls from the 11th grades promoting their self-education and training their least developed physical qualities.

The sample of the research included one experimental and one control group, each consisting of 24 female subjects (n = 48) from the X school in Klaipėda. The subjects of each group were selected using the random sampling method. Each group had two weekly PE lessons according to the Lithuanian General Physical Education Curriculum.

Testing physical fitness based on the guidelines of the Eurofit tests was performed in the middle of September, 2003 and the middle of April, 2004. The pedagogical experiment lasted for 7 months. To determine physical fitness of subjects, the Eurofit tests were used in the following order: sit-and-reach, standing broad jump, sit-ups, bent arm hang, shuttle run 10 × 5 metres. The results were assessed according to the National Eurofit Reference Scales.

It was found that physical fitness of girls from the 11th grades was low: according to the Lithuanian Eurofit Reference Scales, the test score in standing broad jump was 3, the test score in sit-and-reach, sit-ups and shuttle run 10×5 m was 4 and the test score in bent arm hang was 5. In the first tests it was determined that the least developed traits in subjects were the strength of their leg and abdominal muscles and suppleness. For the experimental group, the physical education programme was modified with greater focus on training strength and suppleness.

PE lessons for the experimental group included training pupils' awareness about PE and promoting of self-education. For this reason, the girls were taught to calculate and evaluate their body mass index, they had theoretical lessons about the importance of strength and suppleness as physical qualities and methods how to train them, the importance of exercising, methods of stretching and personal exercising, self-assessment of physical condition.

The programme designed to promote the need for self-development and to train strength and suppleness had a positive effect on physical fitness changes in girls: most of physical qualities increased significantly in girls from the experimental group.

Keywords: *physical fitness, physical qualities, physical self-development.*

INTRODUCTION

Physical fitness among Lithuanian pupils has been constantly decreasing (Volbekienė, Kavaliauskas, 2003; Volbekienė, Griciūtė, 2007). Two (or even three) weekly Physical education (PE) lessons at school can not compensate adequately the lack of schoolchildren's physical activity. If supplementary educational measures are not provided, the tendency toward decreasing physical activity in pupils can be observed starting already from the fifth grade (Kardelis et al., 2001). Therefore, in search for effective ways to promote physical activity, schoolchildren's PE has to be supplemented with measures that can form the need for physical self-development.

PE teachers have an important role in developing schoolchildren's awareness about the relations between physical activity and health and in forming the need for physical self-development.

It is essential to seek for schoolchildren's understanding of the asignments given to them and to make certain that their requirements are suitable for each pupil (Ивашкене, 1990; Hopkins et al., 1998). To achieve these objectives, we need to know pupils' needs, provide them with information about the effect of physical exercises on human health, body shape and physical fitness.

Although physical self-education has been investigated in terms of developing effective technologies to promote students' physical self-education (Tubelis, 2001; Poteliūnienė et al., 2006), not much research deals with different means of influence, that would attempt to form a positive attitude in schoolchildren of different ages toward physical self-development as one of the factors capable of affecting their health. Few studies have analysed the effects of consistent training of the least developed physical qualities on the physical fitness changes in schoolchildren.

In the present study the research problem is revealed by a problem-oriented question, whether knowledge about PE and healthy lifestyle, the development of skills needed for self-awareness and self-control of physical condition, physical activity that meets personal needs, promotion of the need for physical self-development and training of the least developed physical qualities are effective means of increasing physical fitness in girls from the upper grades.

Research object is the changes in physical fitness of girls from the upper (11th) grades.

Hypothesis. Knowledge about PE and healthy lifestyle, learning how to observe and control personal physical condition, promotion of the need for physical self-development and training of the least developed physical qualities have a positive effect on physical fitness changes in girls from upper grades.

The aim of the research is to determine the changes in physical fitness of girls from the upper grades through their self-education and training of the least developed physical qualities.

The objectives based on the research aim were the following**:**

1. To determine and evaluate physical fitness of the girls of the 11th grades.
2. To identify the subjects' least developed physical qualities, to design the programme for training them and a physical self-education program.
3. To determine the effect of the designed programme on subjects' physical fitness.

The following **methods** were applied in conducting the research**:** 1. Literature review. 2. Antropometrics. 3. Physical fitness testing. 4. Pedagogical experiment. 5. Mathematical statistics.

The scope of the research included one experimental and one control group, each of them consisting of 24 female subjects (n = 48) from the X school in Klaipėda. The subjects for each group were selected using the random sampling method. The data for each group were tested for normal distribution using a Kolmagorov-Smirnov test. Each group had two weekly PE lessons according to the Lithuanian General Physical Education Curriculum.

Antropometrical measurements (height, weight) were performed, including body mass index (BMI) (Heyward, 2002). Testing of physical fitness based on the guidelines of the Eurofit tests was performed in the middle of September, 2003 and the middle of April, 2004 (the pedagogical experiment lasted for 7 months). To determine physical fitness of subjects, the Eurofit tests were used in the following order: sit-and-reach, standing broad jump, sit-ups, bent arm hang, shuttle run 10×5 metres. The results were assessed according to the national Eurofit Reference Scales (*Eurofitas: fizinio pajėgumo testai ir metodika,* 2002).

In the first tests it was determined that the least developed traits in subjects were strength of their leg and abdominal muscles and suppleness. For the experimental group, the physical education programme was modified with greater focus on training strength and suppleness.

The exercises used for leg muscle training were jumps from a gymnastics bench, jumps with bent knees, jumps over a bench, jumps over a rope, high and long jumps, sit-ups, tiptoes, multiple jumps. The exercises used to train abdominal muscles were movements with legs in a standing and lying position, different passes of a stuffed ball with legs in a lying position, throws of a stuffed ball in a sitting and kneeling position, crunches, sit-ups, knee ups from a hanging position. Flexibility was trained through stretching exercises, bends, leaning with and without tools movements.

PE lessons for the experimental group included training of pupils' awareness of PE and promotion of self-education. For this reason, the girls were taught to calculate and evaluate their body mass index (BMI), they had theoretical lessons about the importance of strength and suppleness as physical qualities and methods how to train them, the importance of exercising, methods of stretching and personal exercising, self-assessment of physical condition. The physical education programme of the control group was not modified.

The research results have been processed by using the SPSS 13.0 software. The statistical signíficange was calculated according to a Student's *t* test and the level of reliability *p*.

RESEARCH RESULTS AND ANALYSIS

At the beginning of the research, the mean height of the control group was 170.1 ± 2.2 cm, while at the end of the research the mean height was 171.2 ± 2.3 cm; the mean height of the experimental group was 171.2 ± 2.47 and 171.5 ± 2.7 cm respectively (Fig. 1).

The girls' weight during the research period practically did not change: at the beginnning of the research the mean weight of the control group was 57.1 ± 2.4 kg and at the end of the research the mean weight was 57.2 ± 2.37 kg ($t = 0.13$; $p > 0.05$) (Fig. 2), while the mean weight of the experimental group was 57.4 ± 3.17 and 57.3 ± 3.47 kg ($t = 0.87$; $p > 0.05$) respectively. The mean height and weight of the control and experimental groups were similar at the beginning and the end of the research ($p > 0.05$) and did not change significantly during the research ($p > 0.05$).

After calculating BMI (kg / m^2), it was determined that the data obtained from the two groups did not differ ($p > 0.05$) and were within 19.5—19.7 kg / m^2 limits (Fig. 3).

The results of the control and experimental groups in the first sit-and-reach test were similar ($p > 0.05$): 25.5 ± 4.17 and 25.8 ± 4.37 cm respectively (Fig. 4).

After the experimental period, the suppleness in the control group increased by 1.2 cm; however, the difference between the first and the second test was not statistically significant ($t = 0.81$; $p > 0.05$). The suppleness in the experimental group increased by 4.3 cm and was 30.1 ± 4.5 cm. The difference between the first and the second tests was statistically significant ($t = 2.89$; $p < 0.01$). According to the Lithuanian

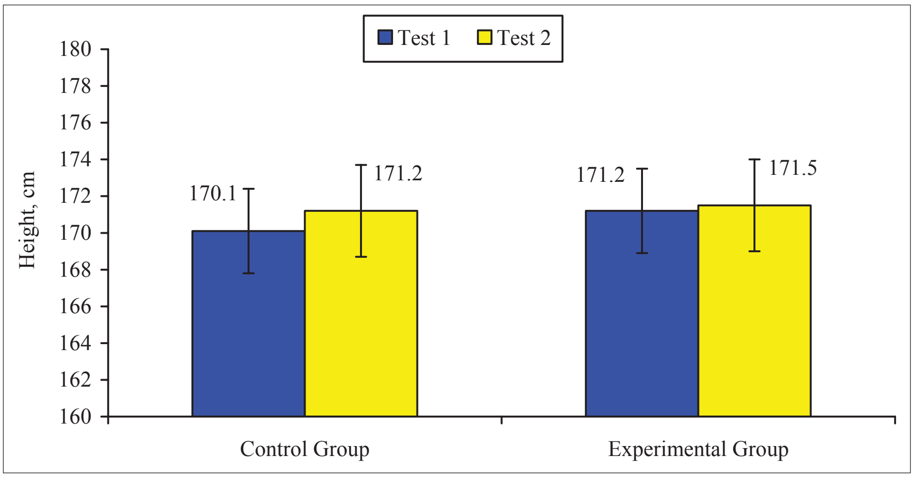


Figure 1. **Girls' height ($\bar{x} \pm S\bar{x}$)**

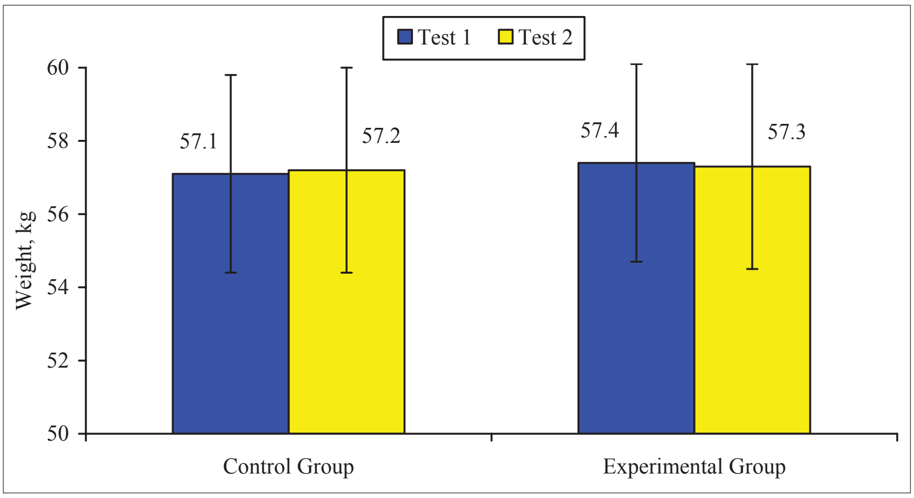


Figure 2. **Girls' weight ($\bar{x} \pm S\bar{x}$)**

Figure 3.
Girls' Body mass index ($\bar{x} \pm S\bar{x}$)

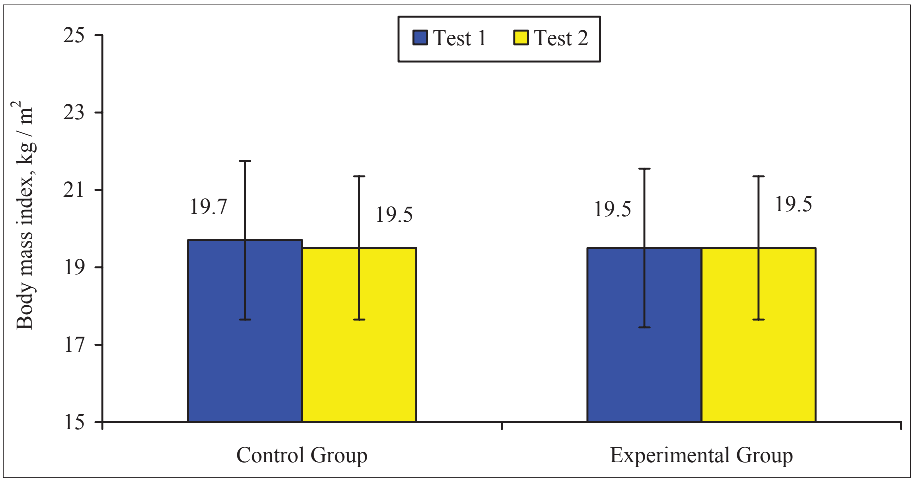


Figure 4. **The results of girls' Sit-and-reach test ($\bar{x} \pm S\bar{x}$)**

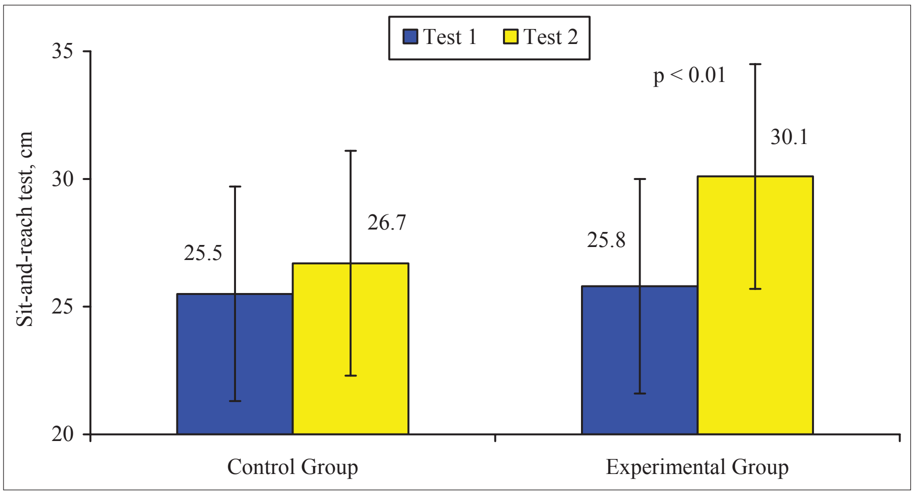
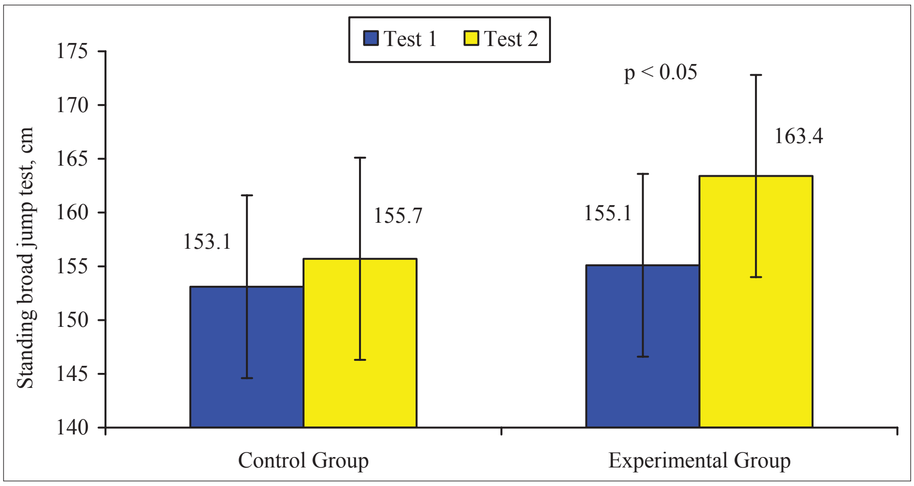


Figure 5. **The results of girls' Standing broad jump test ($\bar{x} \pm S\bar{x}$)**



Eurofit Reference Scales (2002), in the first test the score in the control and experimental groups was 4; however, in the second test the control group score was 5, while the score in the experimental group was 6.

In the first standing broad jump test, the mean result of the control group was 153.1 ± 10.17 cm (Fig. 5) and, in the second test, the mean result was 155.7 ± 10.27 cm. Thus the change was not statistically significant ($t = 0.72$; $p > 0.05$). In the first test, the girls from the experimental group jumped 155.1 ± 9.2 cm, and in the second test — 163.4 ± 9.17 cm. The increase of 8.3 cm was statistically significant ($t = 2.56$; $p < 0.05$). According to the national Eurofit Reference Scales, the score of the control group was 3 in the first and second tests, while the score of the experimental group was 3 in the first test and 4 in the second test.

In the first sit-ups test, the control group performed 24.0 ± 3.2 N / 30 s, while in the second test

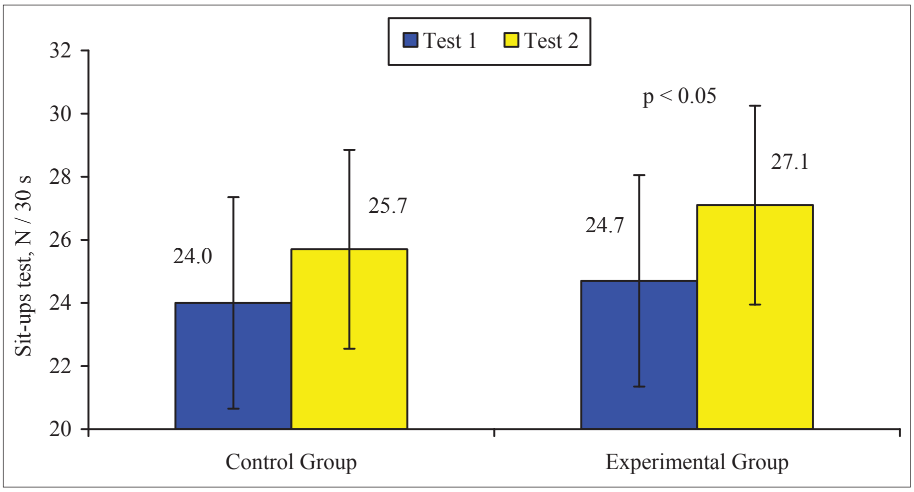


Figure 6. **The results of girls' Sit-ups test ($\bar{x} \pm S\bar{x}$)**

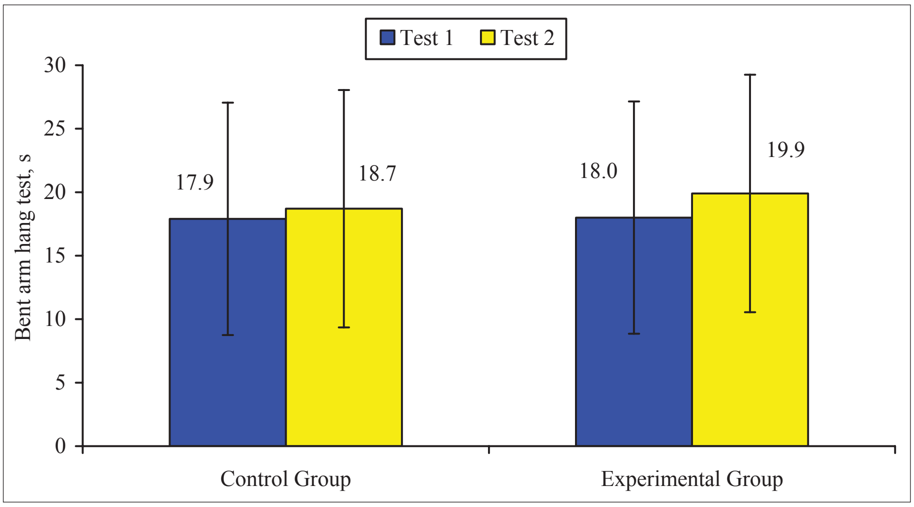


Figure 7. **The results of girls' Bent arm hang test ($\bar{x} \pm S\bar{x}$)**

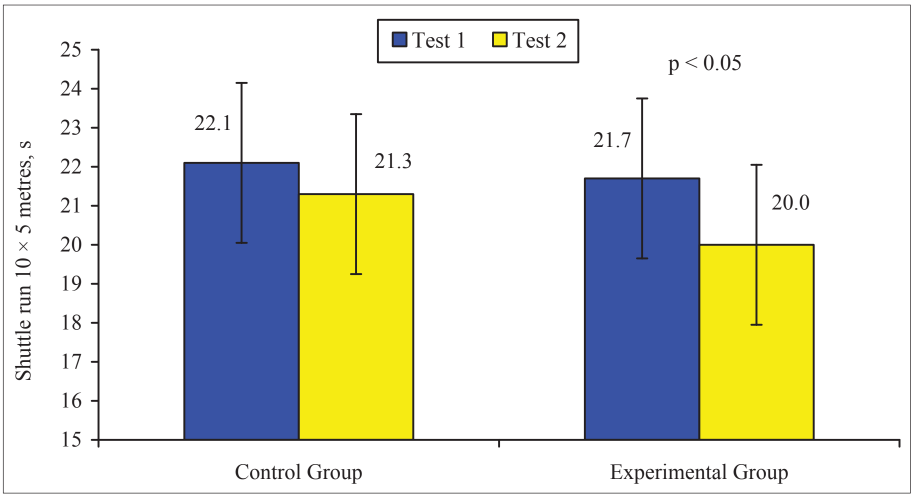


Figure 8. **The results of girls' Shuttle run 10 × 5 metres ($\bar{x} \pm S\bar{x}$)**

the control group performed 25.7 ± 3.3 N / 30 s (Fig. 6). The experimental group performed 24.7 ± 3.5 and 27.1 ± 3.0 N / 30 s respectively. Thus the results of the experimental group improved by 2.4 N / 30 s. The difference in the experimental group between the first and the second test was statistically significant ($t = 2.09$; $p < 0.05$), while the difference in the control group was insignificant ($p > 0.05$). According to the national Eurofit Reference Scales, the control group in the first test scored 3 and in the second test it scored 5, while the scores of the experimental group were 4 and 6 respectively.

In the first bent arm hang test, the result of the control group was 17.9 ± 9.1 s and in the second test the result was 18.7 ± 9.3 s (Fig. 7). The result of the experimental group was 18.0 ± 9.2 s and 19.9 ± 9.4 s respectively. The increase in performing the bent arm hang test was observed in both groups ($p > 0.05$). In the first and the second test the girls from the control group scored 5 according to the national Eurofit Reference Scales, while the scores of girls from the experimental group were 5 in the first test and 6 in the second test.

The mean result of the control group in the first shuttle run 10 × 5 m test was 22.1 ± 2.1 s and in the second test the mean result was 21.3 ± 2.0 s (Fig. 8). The results of the control group in the shuttle run 10×5 m over the experimental period statistically did not change ($t = 1.62$; $p > 0.05$). On the other hand, the result of the experimental group in the first shuttle run 10 × 5 m test was 21.7 ± 2.0 s, while in the second test the result was 20.0 ± 2.1 s. This increase was statistically significant ($t = 2.34$; $p < 0.05$). According to the Lithuanian Eurofit Reference Scales, the control and experimental groups in the fist test scored 4. However, in the second test the score of the control group was 5, while it was 6 in the experimental group.

DISCUSSION

The compararative analysis of subjects' height and weight according to the national Eurofit Reference Scales (*Eurofitas: fizinio pajėgumo testai ir metodika,* 2002) and Children's Growth Scales (Tutkuvienė, 1995) indicates that the subjects' data corresponds to the mean data of Lithuanian girls from the upper grades. During the experimental period the girls' height and weight from the control and experimental groups increased insignificantly.

In recent years scientists from other countries pay more attention to the BMI (Himmes, Dietz, 1994; Heyward, 2002). Body mass is normal when BMI is 20—25 kg / m^2, and body mass is ideal when BMI is 22 kg / m^2. In this research the subjects' BMI was 19.5—19.7 kg / m^2 and reflected the girls' general trend toward slenderness that has been noted by D. Lauzier et. al. (1992).

Physical fitness of girls from the upper grades is low: according to the Lithuanian Eurofit Reference Scales, the test score in standing broad jump was 3, the test score in sit-and-reach, sit-ups and shuttle run 10 × 5 m was 4 and the test score in bent arm hang was 5. According to the Lithuanian Physical Education Badge (1996), the girls in the first bent arm hang test scored 1 point and in other tests girls did not score even this lowest point. In the second sit-ups test the control group scored 1 point, while the experimental group scored 3 points. In both bent arm hang tests the control group scored 1 pont while the experimental group scored up to 2 points. In the shuttle run 10×5 m test the experimental group scored 6 points.

The programme designed to promote the need for self-development and to train strength and suppleness purposefully had a positive effect on the changes in the girls' physical fitness: the results of the experimental group in standing broad jump, sit-ups, sit-and-reach and shuttle run 10×5 m tests increased significantly ($p < 0.05$), while in the control group only a slight increase of physical fitness was observed. These observations correspond to the data obtained by researches who noted that the parameters of pupils' physical fitness increase very insignificantly throughout the school year (Zuozienė, 1998). The research data supported the findings of the previous research that the least developed physical qualities if trained purposefully would improve (Ивашкене, Скирене, 2005). The increase of suppleness in girls as the result of systematic education has been determined by V. Paliušienė et al. (2003).

The data obtained in the research support the opinion of other authors who state that in PE lessons physical load has to be planned and analysed and that PE teachers have to choose moderate physical activity, teach pupils health-enhancing physical exercises and instil in them the joy of movement (Feingold, Barrete, 1991). Special attention in PE lessons has to be given to the transfer of knowledge, skills and abilities how to exercise for self-development (Bunker, 1998; Zuozienė, 1998).

In conclusion, it can be stated that if in PE lessons girls' self-education is promoted by different means and more attention is given to the training of the least developed physical traits (in the case of this research to strength and suppleness), physical fitness parameters increase faster compared to the increase when the standard methods are used. The positive effect of educational factors on physical fitness has been determined by I. J. Zuozienė (1998), O. Batutis and K. Kardelis (1998).

The research hypothesis was comfirmed: knowledge about PE and healthy lifestyle, learning to observe and evaluate personal physical condition, physical self-education and training of the least developed physical qualities have a positive effect on the change of physical fitness in girls from the upper grades.

CONCLUSIONS

1. Physical fitness of girls from the upper grades is low: according to the Lithuanian Eurofit Reference Scales, the test score in standing broad jump was 3, the test score in sit-and-reach, sit-ups and shuttle run 10×5 m was 4 and the test score in bent arm hang was 5.
2. The least developed physical qualities in the girls from the upper grades are strength and suppleness.
3. The programme designed to promote the need for self-development and to train strength and suppleness had a positive effect on physical fitness changes in girls: most of physical qualities improved significantly in girls from the experimental group ($p < 0.05$).

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VIENUOLIKTOKIŲ FIZINIO PAJĖGUMO KAITA SKATINANT FIZINĘ SAVIUGDĄ IR UGDANT SILPNIAUSIAI IŠLAVINTAS FIZINES YPATYBES

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SANTRAUKA

Tyrimo tikslas — nustatyti vienuoliktokių fizinio pajėgumo kaitą skatinant fizinę saviugdą ir ugdant silpniausiai išlavintas fizines ypatybes.

Tiriamąją imtį sudarė 24 eksperimentinės ir 24 kontrolinės grupės merginų (n = 48) iš Klaipėdos N mokyklos. Eksperimentinės ir kontrolinės grupės imtys buvo sudarytos atsitiktinės atrankos būdu. Abi grupės turėjo dvi savaitines kūno kultūros pamokas, kurios vyko pagal Lietuvos bendrąsias kūno kultūros programas.

Fizinio pajėgumo testavimas pagal Eurofito programos reikalavimus atliktas 2003 m. rugsėjo viduryje ir 2004 m. balandžio viduryje. Pedagoginio eksperimento trukmė — 7 mėnesiai.

Fiziniam pajėgumui nustatyti buvo naudojami Eurofito testai išvardyta seka: „Sėstis ir siekti“, šuolis į tolį iš vietos, „Sėstis ir gultis“, kybojimas sulenktomis rankomis, „10 × 5 m bėgimas šaudykle“. Gauti rezultatai vertinti pagal Eurofito orientacines vertinimo skales (*Eurofitas. Fizinio pajėgumo testai ir metodika*, 2002).

Atlikus pirmą testavimą nustatyta, kad vienuoliktokių fizinis pajėgumas prastas: pagal Eurofito orientacines vertinimo skales 3 balų vertinimo ribose yra šuolio į tolį rezultatai, 4 balų — testų „Sėstis ir siekti“, „Sėstis ir gultis“, testo „10 × 5 m bėgimas šaudykle“, 5 balų — kybojimo sulenktomis rankomis. Išaiškėjo, kad silpniausiai išlavinta yra tiriamųjų kojų ir pilvo raumenų jėga bei lankstumas. Eksperimentinei grupei buvo sudaryta kūno kultūros programa, kurioje daugiau dėmesio skirta jėgos ir lankstumo lavinimui. Per kūno kultūros pamokas buvo ugdomas eksperimentinės grupės merginų sąmoningumas kūno kultūros srityje, skatinama fizinė saviugda. Tuo tikslu merginos buvo išmokytos apskaičiuoti savo kūno masės indeksą ir jį įvertinti, joms buvo vestos teorinės pamokos apie jėgos ir lankstumo fizinių ypatybių reikšmę ir ugdymo metodiką, mankštos svarbą, raumenų tempimo ir savarankiško mankštinimosi metodiką, mokoma vertinti savo fizinę būklę.

Fizinės saviugdos skatinimo bei jėgos ir lankstumo ugdymo programa turėjo teigiamą įtaką merginų fizinio pajėgumo kaitai: eksperimentinėje grupėje smarkiai pagerėjo daugumos fizinių ypatybių rodikliai.

Raktažodžiai: fizinis pajėgumas, fizinės ypatybės, fizinė saviugda.

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THE DRIVE FOR MUSCULARITY AMONG ADOLESCENT BOYS: ITS RELATIONSHIP WITH GLOBAL SELF-ESTEEM

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ABSTRACT

Among adolescent boys a higher drive for muscularity is related with poorer self-esteem and more symptoms of depression. There is an agreement that male athletes, in general, experience greater body satisfaction compared to nonathletes of the same age, however there is lack of studies to demonstrate how participation in various sports relates in terms of drive for muscularity and global self-esteem among adolescent boys. One hundred adolescent boys (mean age — 14.63 ± 1.97) took part in the study. 29 boys were at 6th grade, 34 — at 8th, and 37 — at 10th grade. All the participants completed the self-constructed questionnaire consisting of 21 items. The following blocks of questions or statements were included into the questionnaire: demographic variables (age, grade, the living place (urban or rural)), global self-esteem (Rosenberg's (1989) questionnaire of self-esteem), body esteem (the satisfaction with one's own appearance and appearance of various body parts), and involvement to after-school activities (involvement in activity (for at least half a year) was considered as formal belonging to a club, school, or group, but not independent activities at the leisure time). The participants also completed the questionnaire Drive for Muscularity Scale (DMS) (McCreary, Sasse, 2000). Results showed no significant differences in the drive for muscularity among the boys involved in different after-school activities, while the greatest drive was demonstrated by adolescents involved in dancing. The adolescents involved and not involved in sport did not show significant differences in global self-esteem and overall appearance evaluation while the lowest dissatisfaction was common to the boys involved in dancing. The drive for muscularity was not significantly related to poorer overall appearance evaluation and self-esteem among adolescent boys involved in various after-school activities. Involvement in sport activities might mediate the negative effect of the drive for muscularity. The drive for muscularity might also be closely related to the demands of sport activities, but not to the improvement of personal appearance. However, it was found that dissatisfaction with body image and weight was more closely related to low self-esteem among girls, but not among boys, so our study partially supported the previous findings. The future studies should investigate the drive for muscularity, body-esteem and self-esteem interrelation in the samples of adolescent boys involved in recreational and professional sport.

Keywords: *adolescent boys, drive for muscularity, self-esteem, afterschool activities.*

INTRODUCTION

Western cultures are blamed for emphasizing physical beauty. Despite the fact that body appearance is mainly an object of women's concerns, there are many signs that dissatisfaction with one's own body among boys and men makes them suffer. Many men are motivated to achieve the prowess and "physicality" that have become the essential ingredient of male attractiveness. Research has suggested that people assume muscular men to be more masculine (McCreary et al., 2005). Some researchers argue that "men are susceptible to a greater variety of weight concerns than females because the ideal to which men aspire is much more complex than thinness norm women embrace" (Corson, Andersen, 2002). As feminism has changed females' perceptions of themselves and their socially constructed gender roles, the perceptions of maleness have also changed. Women are achieving more social power and independence, so they can be more selective in the mates they choose, which is why muscularity might be an attempt to preserve the traditional notion of the male role (Olivardia, 2002). The studies demonstrate that the commercial value of men's body has increased over the past twenty years (Pope et al., 2001).

Some authors (Pope et al., 2000) point out that the modern generation's obsession with fitness and appearance is the concept of the "supermale" which has infected millions of young men with an "Adonis complex" (V-shaped muscular body as the Greek half — man, half — god Adonis represented). Seeking for "appearance success" is related to the increase of eating disorders, compulsive exercising, appearance obsession, use of not prescribed pharmaceuticals and finally with muscular or body dysmorphia. There is abundance of studies giving reliable empirical evidence on the topic (McCreary, Sasse, 2000; Cohane, Pope, 2001; Pedersen, Wichstrom, 2001; Choi et al., 2002; Raudenbush, Meyer, 2003).

The studies show that dissatisfaction with body image is common among adolescent boys in Western cultures (Furnham et al., 2002). Adolescence is an important period for the development of body image, because a number of normative developmental challenges influence body image, including pubertal development, gender role intensification. It is believed that this transition is more stressful for girls, while some researchers do believe opposite because of the complexity of the development of male body image. Studies show that the ideal male body must be muscular and lean enough at the same time (Raudenbush, Meyer, 2003).

In industrialized countries, body image and overall physical appearance is one of the most important predictors of adolescents' global self-esteem (McCreary, Sasse, 2000). However, some sports and forms do encourage preoccupation with a body shape, especially among adolescent girls. Males involved in sports emphasizing bulk, power, and muscular definition may also be susceptible to negative body image, because the perceptual discrepancy between their ideal (hypermuscular ideal featured in movies, bodybuilding and wrestling) and actual body image.

The conception "drive for muscularity" is used trying to explain an individual's perception of his / her muscularity and conviction that bulk should be added to his or her body frame, in the form of muscle mass (irrespective of a person's percentage of actual muscle mass or body fat) (McCreary, Sasse, 2000). Among adolescent boys a higher drive for muscularity is related with poorer self-esteem and more symptoms of depression compared to girls (McCreary, Sasse, 2000). It is widely agreed that male athletes in general experience greater body satisfaction, especially football players and body-builders compared to nonathletes of the same age, however there are not many studies demonstrating how participation in various sports and after-school activities are related to the drive for muscularity and global self-esteem among adolescent boys. **The aim of this study** was to test the associations between the drive for muscularity and global self-esteem in adolescent boys involved in various after-school activities.

PARTICIPANTS, INSTRUMENT AND PROCEDURE

Research participants were students from the sixth, eighth, and tenth grades of Jurbarkas secondary schools. The sample contained 110 students from four secondary schools. 10 questionnaires were not filled in fully or were damaged, and therefore they were rejected. Consequently, the questionnaires of 100 boys aged between 11 and 17 years, mean (SD) 14.63 (1.97) were analyzed. 29 boys were in the 6^{th} grade, 34 — in the 8^{th}, and 37 — in the 10^{th} grade. All the participants completed the self- constructed questionnaire consisting of 21 items. The following blocks of questions or statements were included into the questionnaire: demographic variables (age, grade, the living place (urban or rural)), global self-esteem (M. Rosenberg's (1989) questionnaire of self-esteem), body esteem (the satisfaction with one's own appearance and the appearance of different parts of the body), and involvement in after-school activities (involvement in an activity (for at least half a year) meant formal belonging to a club, school or group, but not independent activities at the leisure time). Besides participants completed the Drive for Muscularity Scale (DMS) (McCreary, Sasse, 2000). The DMS is a 15-item measure of the extent to which people desire to have a more muscular body. Higher scores reflect a greater drive for muscularity. The scale showed high internal consistency in this sample (Cronbach's alpha was 0.8). The questionnaires were filled in during the classes upon prior agreement with teachers. The procedure was carried out by the researchers themselves. Participation of students was based on the principles of anonymity and good will. The pupils were given as much time as they needed. It took about 20 minutes on the average to fill in the questionnaire. The filled ones were collected at once.

Data Analysis. The data were analysed using the statistical package software system SPSS13.0. Bivariate associations were calculated using chi-square (χ^2) criterion (α =0 .05). A one-way analysis of variance (one way ANOVA) was used to test the equality of means.

RESULTS

72 adolescents lived in urban places. 28% of the sample were not involved in some after-school activities. 35% of the boys were involved in sport games, 9% of them went in for combat sports, 11% — power sports (bodybuilding, weightlifting), 6% — dancing, 11% of boys were devoted to music and arts. The involvement in various after-school activities in each grade is presented in Table 1. The involvement in after-school activities decreased in every other grade, though the most distinct decrease was observed in involvement in dancing, music and arts (χ^2 = 16.6; df = 10; p = 0.08).

One-way ANOVA test showed that there were no statistically significant differences in global self-esteem among adolescents who were and were not involved in sports, respectively — 19 (3.6) versus 19.07 (3.6). There were no statistically significant differences in the global self-esteem among adolescents involved and not involved in different after-school activities (mean (SD) — 18.78 (3.86), range 7—28), F = 0.84; df = 5, p = 0.52, though the lowest mean of the global self-esteem was typical of adolescent boys involved in music and arts and the highest — for those involved in power sports (Table 2). There were no differences in global self-esteem between adolescents living in urban and rural places and learning in different grades.

23% of adolescent boys evaluated their weight as too low, while 12% of the sample judged their weight as too high. 42% of boys reported dissatisfaction with their overall body appearance. The dissatisfaction with body appearance strongly depended on the evaluation of the body weight: the highest dissatisfaction was expressed by those adolescents who judged their weight as too

	Not involved	Sports games	Combat sports	Power sports	Dancing	Music and arts	Total
6th grade	8 (28.6)	4 (11.4)	5 (55.6)	3 (27.3)	3 (50)	6 (54.5)	29 (29)
8th grade	8 (28.6)	15 (42.9)	1 (11.1)	4 (36.4)	3 (50)	3 (27.3)	34 (34)
10th grade	12 (42.9)	16 (45.7)	3 (33.3)	4 (36.4)	0	2 (18.2)	37 (37)

Table 1. **The distribution of adolescent boys involved in various after-school activities by grade**

Note. In parenthesis — percentage distribution of students in sample.

	Not involved	Sports games	Combat sports	Power sports	Dancing	Music and arts
Mean (SD)	19.07 (3.57)	18.66 (3.54)	18.89 (4.40)	20.18 (3.43)	18.83 (3.37)	16.91 (5.61)

Table 2. **The distribution of global self-esteem mean among groups involved and not involved in various after-school activitie**

	Not involved	Sports games	Combat sports	Power sports	Dancing	Music and arts	Total
Dissatisfied	17 (60.7)	15 (42.9)	3 (33.3)	4 (36.4)	0	3 (27.3)	42 (42)

Table 3. **The distribution of dissatisfaction with overall bodily appearance among adolescent boys by involvement in after-school activities**

Note. In parenthesis — percentage of students in the sample.

	Not involved	Sports games	Combat sports	Power sports	Dancing	Music and arts
Drive	43.3 (12.2)	42.3 (16.2)	40.5 (10.3)	44.7 (16.4)	52.8 (24.9)	36.2 (13.8)
Muscular dissatisfaction	26.6 (7.8)	24.9 (8.9)	24.7 (6.4)	26.5 (9.4)	26.8 (12.2)	21.8 (10.5)
Behavior for muscle increase	15.4 (5.5)	15.9 (7.5)	14.9 (4.6)	16.3 (6.6)	22.8 (11.6)	13.3 (4.3)

Table 4. **The mean (SD) distribution of the drive for muscularity in adolescent boys by involvement in after-school activities**

high and too low compared to the adolescents who evaluated their weight as normal, respectively: 9 (75%) and 15 (65.2%) versus 18 (27.7%), $\chi^2 = 15.9$; df = 2; $p < 0.01$). It is worth noting that the evaluation of the overall bodily appearance did not depend on the grade, but it depended on the involvement in sports: adolescent boys involved in sports activities were significantly more satisfied with their overall body appearance: 39 (63.9%) versus 11 (39.3%), $\chi^2 = 4.7$; df = 1; $p < 0.05$. Adolescent boys involved in dancing expressed the lowest dissatisfaction with their overall body appearance, $\chi^2 = 9.8$; df = 5; p = 0.08 (Table 3).

One-way ANOVA showed that there were no statistically significant differences in the global self-esteem among groups of adolescents evaluating their own body weight in different ways, while the lowest scores of global self-esteem were given by the adolescent boys who thought that their body weight was too low compared to those who judged their weight as normal or too high, respectively (mean (SD)): 17.9 (3.97) versus 19.1 (3.77) and 18.6 (4.25). The same tendency was observed comparing the groups of different body appearance evaluation: the greater dissatisfaction was related to the lower global self-esteem, respectively — 18.2 (4.0) and 19.2 (3.69).

The drive for muscularity increased with the grade, accordingly 41.4 (14.6) in 6th grade, 41.7 (17.6) in 8th grade, and 44.5 (13.2) in the 10th grade, F = 0.43, df = 2; p = 0.65. It was higher among adolescents living in urban places compared to rural, respectively: 44.3 (15.5) versus 38.4 (13.4), F = 3.1; df = 1, p = 0.08. The lowest drive for muscularity was demonstrated by the boys who evaluated their weight as too high compared to those who thought that their weight was normal or too low, respectively: 35.2 (10.4) versus 43.9 (15.7) and 43.04 (14.8), F = 4.73; df = 2; p = 0.2.

There was no significant relationship between the drive for muscularity and the overall body appearance evaluation, but the boys who evaluated their appearance higher, scored lower on the drive for muscularity scale, respectively: 41.1 (14.9) versus 44.7 (15.3), F = 1.43; df = 1, p = 0.23. There was no significant relationship between the drive for muscularity and the self-esteem as well.

No significant differences were found between the drive for muscularity among adolescent boys involved and not involved in sport, respectively: 43.5 (16.4) versus 43.3 (12.2). It is interesting to note that, though the higher drive for muscularity was more common among the boys involved in power sports, the highest muscular drive was demonstrated by the adolescents involved in dancing, and the lowest — among those involved in music and arts (Table 4). The range was 15—90 in this sample, mean (SD) — 42.6 (15.1). Adolescents living in urban places demonstrated higher drive for muscularity compared to those living in rural places, respectively: 44.3 (15.5) versus 38.4 (13.4), F = 3.1; df = 1; p = 0.08. The mean distribution of the dissatisfaction with the muscle mass (mean on the scale — 25.3 (8.78), range — 7—42) demonstrated that the lowest dissatisfaction was common to adolescent boys involved in music and arts activities (F = 0.56; df = 5; p = 0.73). The highest scores in behavior scale were demonstrated by the boys involved in dancing, while the lowest — by those involved in music and arts (F = 1.7; df = 5; p = 0.14).

DISCUSSION

The aim of this observational study was to determine the relationship between the drive for muscularity and global self-esteem in adolescent boys involved in various after-school activities. While other studies show that the higher drive for muscularity relates with the poorer global self-esteem (McCreary, Sasse, 2000), our study shows the opposite: the higher drive for muscularity is related to the higher body and global self-esteem among adolescent boys involved in sport. Some studies (Koivula, 1999; Puniskiene, Laskiene, 2006) have shown that individuals who participate in sports have higher self-esteem than nonparticipants, however other researchers (Marsh, Jackson, 1986; Richman, Shaffer, 2000) have reported a weak link between sports participation and global self-esteem. Other studies (Bowker et al., 2003) emphasize that global self-esteem depends on gender role orientation and that highly feminine individuals benefit from recreational and noncompetitive sports activities and the opposite.

Involvement in sport activities might mediate the negative effect of the drive for muscularity. The drive for muscularity might also be closely related to the demands of sport activities, but not to the personal appearance improvement. However, it was found that dissatisfaction with body image and weight was more closely related to low self-esteem for girls, but not for boys (Furnham et al., 2002), so our study partially supported the previous findings. The future studies should investigate the drive for muscularity, body-esteem and self-esteem interrelation in the samples of adolescent boys involved in recreational and professional sport.

As we have expected the lowest drive for muscularity was demonstrated by boys involved in music and arts, though the highest drive for muscularity was demonstrated by adolescent boys involved in dancing activities. We were surprised to find that because dancing as an activity is traditionally attributed to the feminine activities in Western societies. The results might be explained by the notion that dancing as aesthetical activity requires emphasizing their appearance from its participants (males), so the participants (adolescents in this study) strive for the traditionally accepted male body image. The other explanation might be that men' participation in traditionally feminine activities forces them to preserve their traditional muscular body image.

The results of our study replicate the other findings (Furnham et al., 2002; Sweeting, West, 2002), which concluded that men's satisfaction with their body weight differs — some of them want to increase their body mass, while the significant majority wants to decrease it. The highest dissatisfaction with the global appearance was demonstrated by those boys who judged their weight as too low and too high. The tendency was noticed that evaluation of body mass as too low was related to the poorer global self-esteem. Interestingly enough, evaluation of body mass as too low, but not the drive for muscularity was related to poorer global self-esteem in our study.

While the drive for muscularity was not related to the poorer global self-esteem in this sample, the health educators should pay attention to the self-esteem of boys involved in music and arts activities. The lowest scores of their global self-esteem might be explained by the global change in the values occuring after the independence of Lithuania, when the most fashionable image of the men was related to the aggressive behavior and appearance. In the terms of body image, boys involved in sports, especially power and combat sports, have and advantage compared to those involved in delicate activities, because sport still plays a key role in the construction of "popular" masculinity for boys (Robertson, 2003). Poor self-esteem might have a life-long lasting effect on the psychosocial health (Mann et al., 2004).

The main limitation of this study is the slender sample, so the results should be verified in more numerous samples. The cross-sectional nature of the study does not let us make cause relationships, so other studies on this topic should have other designs (e. g. prospective) to clarify the effect of participation in various sports on the relationship between the drive for muscularity and the global self esteem.

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PAAUGLIŲ BERNIUKŲ RAUMENINGUMO SIEKIMAS IR JO SĄSAJOS SU BENDRĄJA SAVIGARBA

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SANTRAUKA

Paauglių berniukų raumeningumo siekimas siejamas su prastesniu savęs vertinimu ir depresijos simptomais. Nustatyta, kad vyrai sportininkai yra labiau patenkinti savo kūnu negu nesportuojantys bendraamžiai, tačiau trūksta tyrimų, kurie atskleistų, kokios įvairias sporto šakas kultivuojančių berniukų raumeningumo siekimo ir jų bendrosios savigarbos sąsajos.

Buvo tiriama šimtas paauglių berniukų (amžiaus vidurkis — 14,63 ± 1,97 m.), iš jų 29 berniukai mokėsi šeštoje klasėje, 34 — aštuntoje ir 37 — dešimtoje. Jie užpildė klausimyną, sudarytą iš tokių klausimų blokų: klausimai, nusakantys demografinius kintamuosius (amžių, klasę, gyvenamąją vietą (miestą arba kaimą), atskleidžiantys bendrąją savigarbą (Rozenberg, 1989), pasitenkinimą savo išvaizda, savo kūno dalių vertinimą, dalyvavimą popietinėje veikloje. Dalyvaujančiais popietinėje veikloje buvo laikomi tie moksleiviai, kurie ne mažiau kaip pusę metų lankė ir formaliai priklausė būreliui, popietinio lavinimo mokyklai, klubui, o ne užsiiminėjo veikla savarankiškai. Papildomai moksleiviai užpildė raumeningumo siekimo klausimyną (McCreary, Sasse, 2000).

Rezultatai atskleidė, kad nėra statistiškai reikšmingo skirtumo tarp įvairia popietine veikla užsiimančių berniukų polinkio siekti raumeningumo, nors daugiausia raumeningumo siekia šokius lankantys berniukai. Sportuojantys ir nesportuojantys paaugliai statistiškai reikšmingai nesiskyrė savigarba ir išvaizdos vertinimu, nors išvaizdą geriausiai vertino šokius lankantys berniukai. Įvairia popietine veikla užsiimančių berniukų, tarp jų ir sportuojančių, raumeningumo siekimas nebuvo statistiškai reikšmingai susijęs su prastesniu išvaizdos vertinimu ir bendra savigarba. Rezultatai gali būti paaiškinami šitaip: sportavimas keičia negatyvų raumeningumo siekimo požiūrį, taip pat jis gali būti susijęs su siekimu atitikti sporto šakos reikalavimus, bet ne tam tikro išvaizdos siekimo standarto. Nepasitenkinimas savo kūno išvaizda, svoriu yra dažniau susijęs su prastesne savigarba tarp mergaičių, o ne tarp berniukų. Atliktas tyrimas iš dalies patvirtina šiuos duomenis. Tolesni tyrimai turėtų būti orientuoti tirti raumeningumo siekimo, savo kūno vertinimo ir savigarbos ryšius tarp berniukų, užsiimančių rekreaciniu ir pasiekimų sportu.

Raktažodžiai: raumeningumo siekimas, savigarba, popietinės pratybos.

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ATHLETIC IDENTIFICATION OF WOULD-BE SPECIALISTS OF PHYSICAL EDUCATION AND SPORTS AT THE INSTITUTION OF HIGHER EDUCATION

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ABSTRACT

Athletic identification indicates the level of person's identification with a role of an athlete. Different levels of sports identifications are typical of all people: those who are sports professionals as well as those who only exercise. The students at the Lithuanian Academy of Physical Education (LAPE) are prepared to be sports coaches and teachers of physical education, and only some students choose the career of a professional athlete, so their identification with sports activities at the academy and their athletic identification might be rather different. The aim of the research was to reveal the manifestation of would-be physical education and sports specialists' athletic identification at the institution of higher education.

The empirical research involved the triangulation of qualitative and quantitative methods. The questionnaire was used to determine the general tendencies of the research participants' athletic identification, and the interview was meant to establish its content and specific features.

The research results have important implications for the personnel of the institutions of higher education attempting to facilitate student personal growth through participation in sports activities. The links of students' athletic identification with the variables in the higher school environment shows the presence of a pervasive athletic culture (Ferris et al., 2004) which results in the educational experience at the Academy. Athletic culture is experienced by students — athletes during their years of competitive, educational, and social development. Students — athletes' first contact with university environment is mediated through institutions — friends, coaches, practice and competitions. In some cases these factors increase athletes' satisfaction with collegiate experience and promote continued persistence toward a degree.

Research results let us conclude that athletic identification at the institution of higher education is determined by students' activity in sports, their sports aspirations and plans, evaluations of sporting conditions at the higher school and perception of the importance of sports activities. Athletic culture at the institution of higher education is both the precondition and the outcome of students' favorable athletic identification. Research revealed the links between the manifestation of students' athletic identification and the following sociodemographic and other factors: gender, academic achievements and academic identification, sports aspirations, living place, professional identification, feelings and the evaluation of their higher school.

Keywords: *athletic identification, athletic culture, institution of higher education.*

INTRODUCTION

At the institutions of higher education academic personnel have been widely interested in the determinants of students' self perceptions as well as the degree to which such perceptions pervade various achievement domains. One of their viewpoints is that sport participation of students contributes to the perceptions in non-sport related areas. Research evidence suggests that participation in sports activities is related to greater prosocial attitudes among young people (Ryska, 2002). Studies attempting to link sport participation to educational aspirations, popularity among peers, and academic identification have produced diverse results (Chandler, Goldberg, 1990; Sabo et al., 1993). Though sport involvement might have significant potential impact on the perceptions, attitudes and behaviors of students, little empirical research is carried out regarding how the nature of higher school sport experience may impact other experiences and perceptions among its participants. Initial sport research indicates that the athletic role constitutes a meaningful dimension of self-identity and influences various responses of athletes and non-athletes alike (Brewer et al., 1993). An individual with a strong athletic identity would be more likely to interpret sport — related events in terms of how they impact his or her athletic functioning. However, considerably less is known regarding the potential role of athletic identity on the formation of perceptions outside the sport setting (Ryska, 2002). S. Stryker (1978, cit. from Ryska, 2002) originally proposed that greater identification with a particular self -identity dimension increases the tendency for an individual to use the perceptual and emotional aspects of the particular dimension to interpret and respond to situations within other identity — based dimensions.

Athletic identification indicates the level of person's identification with a role of an athlete. Different levels of sports identifications are typical of all people: those who are sports professionals as well as those who only exercise. The students at the Lithuanian Academy of Physical Education (LAPE) are prepared to be sports coaches and teachers of physical education, and only some students choose the career of a professional athlete, so their identification with sports activities at the academy and their athletic identification might be rather different. As Adler and Adler (1994) suggest, athletic career starts with the innocent involvement in games, recreational activities, and it continues up to competitive, and then to professional sport. Though all children play games, very few of them become professional athletes. However, athletic identification is characteristic of people actively engaged in sports, as well of people who only exercise.

Rather than simply comparing the levels of personal identifications between athletes, proper inquiry into this relationship should include a description of the student — athlete's identification with sport (Griffin, 1998, cit. from Ryska, 2002). Thus, the **aim** of the research was to reveal the manifestation of would-be physical education and sports specialists' athletic identification at the institution of higher education.

METHODS

The empirical research involved the triangulation of qualitative and quantitative methods. The questionnaire was used to determine the general tendencies of the research participants' athletic identification, and the interview was meant to establish its content and specific features.

Students' athletic identification was measured applying a scale which was composed on the basis of research on athletic identification (Brewer et al., 1993; Ryska, 2002; Anderson, 2004), as well as students' interview responses. The internal consistency — Cronbach's alpha — of the athletic identification scale was adequate (0.64). It means that the method was valid to measure athletic identification. Other questionnaire questions were meant to evaluate students' sociodemographic indicators, academic achievements and environmental variables. Students' academic achievements were self-reported measures. Statistical data analysis was performed using the package *SPSS 11.0 for Windows.*

The semi-structured interview involved questions reflecting the manifestation of athletic identification introduced in research (Brewer et al., 1993; Murphy et al., 1996; Wiechman, Williams, 1997; Webb et al., 1998). The qualitative content analysis (Strauss, Corbin, 1998), based on interpretation, was used to define students' interaction, motivation and perceptions in the context of the institution of higher education. As we seek to present a holistic view of the researched phenomenon, the qualitative and quantitative data were presented together.

The sample in the quantitative research consisted of 622 (366 boys and 256 girls) 1—4th year students at the Lithuanian Academy of Physical Education. The interview participants were 54 students of the same institution.

RESULTS

Different sporting activity of students might influence their athletic identification. According to the research data 39.4% of the research participants attended training sessions and sought for sports results. Almost the same number of students (36.7%) went to training sessions, but they did not need sports results, and 23.5% of the researched students went to sports classes included in the curriculum. It is quite natural that 74.7% of those who sought for sports results were would-be sports coaches, and only 25.3% — teachers of physical education. Sports sessions without seeking for sports results were attended almost by the same number of students of both specialities: 46.1% of them were would-be teachers of physical education, and 53.9% — sports coaches. Among those, who only attended sports classes according to the curriculum, 66.7% were would-be teachers of physical education, and 33.3% — sports coaches.

Table. **Factors influencing students' athletic identification at the Academy**

Favorable factors for athletic identification	Unfavorable factors for athletic identification (given by some of the students)
● Possibility to increase physical fitness ● Possibility to fortify health ● Possibility to relax after intensive mental work ● Possibility to try many branches of sport ● Possibility to study theoretical aspects of sports ● Possibility to match studies with active participation in sports ● Sports camps ● Enough time for training sessions	● Too much sports theory ● Too intensive training sessions before competitions ● The sports work load is too high, and it interferes with learning ● Sometimes the students' traumas and the conclusions of their medical examination are not taken into account

The research established the links between sports activity and sports aspirations. As many as 29.6% of the research participants claimed that their aim of studies at LAPE was to become a good sportsman / sportswoman, though 40.6% disagreed with that, and 28.9 were not sure about that. The majority of the researched students (56%) were sure that it was obligatory to attend training sessions while studying at the academy, but 24.5% of students claimed it was optional. Even 17.7% of the respondents suggested that good sports results at this higher school were more important than good learning. Though 55.8% did not agree with such a statement, and 25.5% were not sure. However, 28.6% of students thought that a good sportsman could be a good student (40.8% disagreed). It is worth noting that though no significant differences were found between respondents' specialities and the years of studies in evaluating their athletic identification, there was a tendency that as the years went by studies became more important than sports aspirations.

In the *interview* all students despite their sports activity were positive about their sports experience at the academy, but their opinions differed about the amount of sports theory. All the respondents who were active in training sessions and needed sports results indicated that most of all they appreciated the possibilities to match their studies with intensive sports training sessions. To many of them it was the main motivating factor of choosing this higher school because they were capacitated to go to sports camps and to spend much time on training. They suggested that however hard it was to train, the experience was rewarding, interesting, and meaningful. The students felt adverse that at some periods of time (before competitions, etc.) they had too many training sessions (even at weekends), and they did not have enough time for learning. Some of them resented that not always the conclusions of the medical examination or the injuries and traumas of students were heeded. Thus, students' identification with sports at the academy could be influenced by various factors (Table).

The students' opinion imparted in the interview suggests that despite some unfavorable factors the conditions for sports activities and their organization in the academy encouraged students' identification with sports activities which in its turn strengthened their athletic identification in general. All the respondents agreed that sport was very important in their lives and that every student at the academy had to go in for some branch of sport. But when participation in sports was compared to learning, their opinions diverged: some students (mostly those who were actively engaged in sports) preferred sports to learning, others — learning to sports, claiming that however important sport was to the would-be specialists of physical education and sports, it should not be their priority or interfere with their learning. The *factor* analysis of Athletic Identification Scale confirmed this fact. It revealed two factors with the eigenvalues of 1.0 or better. The first factor could be characterized by sports priority over learning (factor loading was 0.82, Cronbach's alpha — 0.70). The most important features of this factor were the wish to become a good sportsman / sportswoman (0.84), and the greater importance of sports results compared to learning outcomes (0.80). The second factor (0.89) can be described by the preference of learning to active participation in sports. The exclusive feature of this factor was the students' attitude that sports should not interfere with learning other subjects.

The significance of those factors was confirmed comparing them with the manifestation of academic identification of the research participants. The first factor (giving prominence to sports) was more typical of students expressing lower levels of academic identification. More students whose academic identification was weaker compared to those with higher academic identification claimed that good sports results were more valuable than academic achievements (23.2 and 12.1% of students respectively; $p < 0.001$), and a good student first of all was a good sportsman / sportswoman (33.6 and 24.8%; $p < 0.01$). The second factor (priority of learning over participation in sports) was more common of students manifesting higher academic identification (56.8 and 43.8%, $p < 0.05$).

As it was mentioned before, students expressing higher academic identification had better grades at the higher school, and they had been better students at the secondary school, as well. Thus we can suppose that students with stronger athletic identification should not have been successful at their studies as their academic identification was weaker. The supposition was confirmed by this study. Inclination for sports was more characteristic of students who had adequate and good grades at the secondary school and less characteristic of those whose grades were very good and excellent (respectively 83.2 and 8.1%, $p < 0.001$), accordingly it was more characteristic of those students who had adequate and good grades at the academy and less characteristic of those whose grades at this higher school were very good and excellent (67.8 and 13.4%, $p < 0.005$). Thus we can draw a conclusion that *students who prefer sports activities over learning manifest lower academic identification and have poorer grades at the academy.*

The first factor (preferring sports activities over studies) was more characteristic of those students who chose to study at the academy because of their fondness of sports compared to those to whom sport was not the main reason to enter this higher school (respectively 27 and 18%, $p < 0.05$). It should be noted that students who believed that the academy should soon become a modern sports university, compared to those who had some doubts about that, were more inclined for sports than learning (31.1 and 19.9%, $p < 0.005$).

It is worth noting that students expressing stronger athletic identification had more favorable attitudes towards their future profession — to teach and to train children. Compared to other students they believed that their profession was as prestigious as of teachers of other subjects (45.1 and 26.1%, $p < 0.001$), and they less agreed with the idea that children could learn polite behavior during the lessons of more serious subjects, but not physical education (60.8 and 21.5%, $p < 0.05$). It is interesting to note that students with higher athletic identification believed that teachers of physical education and coaches had to do research (88.2 and 3.3%, $p < 0.05$). We can conclude that *students expressing stronger athletic identification are more inclined to identify themselves with their future profession.*

It should also be noted that students who were more apt to their sports activities felt better at the academy. More of them were proud that they studied at the LAPE (respectively 77.7 and 3.3%, $p < 0.001$), and more of them would choose the same higher school if they had to (82.9 and 2.0%, $p < 0.001$). They also more cared about the image of the academy (50.3 and 18.3%, $p < 0.05$), and they were inclined to associate their success with the success of the academy (61.2 and 9.1%, $p < 0.01$), more of them did not hesitate to tell others that they studied at this higher school (82.3 and 9.8%, $p < 0.05$). Besides, more of them were sure they did not waste their time at the academy (87.6 and 5.2%, $p < 0.05$) and that they felt safe (62.1 and 16.4%, $p < 0.05$).

Students with stronger academic identification not only felt better at the academy, but they evaluated it more favorably, too. More of them believed that conditions to learn there were good enough, if you were able to make use of them (86.3 and 2.0%, $p < 0.005$). They were also satisfied with the relations with teachers (48.7 and 10.5%, $p < 0.005$) and other students (64.4%, compared to those 14.5% who were not satisfied, $p < 0.01$). More of them believed that the academy was the place to be engaged in serious research (59.9 and 8.6%, $p < 0.001$), and that it was now worth the name of a modern university (63.1 and 11.9%, $p < 0.001$). However, more of them were not satisfied with the services of the academy library (48.7%, compared to the 14.2% of satisfied students, $p < 0.005$).

The research established sports identification differences according to the students' gender. As it was expected, sports identification was more characteristic of male students than female students (70.4 and 29.6%, $p < 0.01$). It was also noticed that stronger sports identification was expressed by students from cities compared to those who had arrived from small towns (respectively 68 and 32%, $p < 0.001$). Besides, higher levels of sports identification were manifested by students who did not have to work while studying (85.3 and 14.7%, $p < 0.05$) and who did not have to pay for their studies (83.2 and 16.8%, $p < 0.05$).

DISCUSSION

The research results have important implications for the personnel of the institutions of higher education attempting to facilitate student personal growth through participation in sports activities.

Athletic identification of students is a specific trait of the Academy. The relations between the manifestation of students' athletic identification and other variables, revealed in this study, are important with regard to education. In the context of the institution of higher education the data between students' sports aspirations and academic identification are of great importance. The present research indicated that sports activities oriented students towards sports achievements and that could have a negative impact on the processes of their academic identification because students actively engaged in sports usually manifest lower levels of academic identification, and thus lower academic achievements. Many of them had lower grades in their secondary school, too. For many of the sporting students the possibility to match high sports aspirations and studies was almost the only possibility to acquire higher university education. Besides, students could enter the Academy not so much for their academic credentials, but for their athletic abilities. So, having entered the Academy, students have problems with their studies not only because of their poor academic preparation, but also for their lack of motivation to put maximal efforts in learning. Other studies also revealed that strong identification with the athletic role contributed to poor academic achievements (Cornelius, 1995). The data of another research with the students of the Academy (Kardelis, Karanauskiene, 2003) indicated that as many as 62% of the research participants, demonstrating lower levels of academic identification, chose their studies at the Academy because of haphazard reasons related to sports activities (various exemptions for students — athletes, less difficult studies compared to other universities, etc.), i. e. without intrinsic motivation.

As it was mentioned above, the links between students' sports and academic aspirations are promiscuous. Research data by E. Snyder and E. Spreitzer (1981, cit. from Ryska, Vestal, 2004) showed that students who were members of college sports teams, had better grades and set higher academic goals for themselves compared to students who were not involved in sports activities. We cannot disagree with E. Geron (1996) that participation in sports develops character and behavioral traits which condition good learning. However, F. Blann (1985) found that students actively engaged in sports did not have necessary learning skills, and their academic and career plans were not mature enough. As we see, this problem area has many unanswered questions. More research in the ratio of athletic and academic identification would help to improve the quality of studies of students who are planning their careers connected with sports.

The links of students' athletic identification with other variables in the higher school environment shows the presence of a pervasive athletic culture (Ferris et al., 2004) which results in the educational experience at the Academy. According to the authors, athletic culture is experienced by students — athletes during their years of competitive, educational, and social development. Unlike many of their peers, students — athletes' first contact with university environment is mediated through institutions — teammates, coaches, practice and competitions — with which they are generally familiar. When affective, these factors increase athletes' satisfaction with collegiate experience and promote continued persistence toward a degree.

CONCLUSIONS

1. Athletic identification at the institution of higher education is determined by students' activity in sports, their sports aspirations and plans, evaluations of sporting conditions at the higher school and perception of the importance of sports activities.
2. Athletic culture at the institution of higher education is both the precondition and outcome of students' favorable athletic identification.
3. The present research revealed the links between the manifestation of students' athletic identification and the following sociodemographic and other factors: gender, academic achievements and academic identification, sports aspirations, living place, professional identification, feelings and the evaluation of their higher school.

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BŪSIMŲJŲ KŪNO KULTŪROS IR SPORTO SPECIALISTŲ SPORTINĖ IDENTIFIKACIJA AUKŠTOJOJE MOKYKLOJE

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SANTRAUKA

Sportinė identifikacija rodo, kokiu lygmeniu asmuo identifikuoja save su sportininko vaidmeniu. Įvairūs sportinės identifikacijos lygmenys būdingi visiems žmonėms: sportininkams profesionalams ir tiems, kurie tik mankštinasi. Lietuvos kūno kultūros akademijoje studentai rengiami dirbti sporto šakos treneriais, kūno kultūros mokytojais, ir tik kai kurie iš jų renkasi profesionalaus sportininko karjerą, todėl jų sportinė identifikacija šioje aukštojoje mokykloje gali būti labai skirtinga. Tyrimo tikslas — atskleisti būsimųjų kūno kultūros ir sporto specialistų sportinės identifikacijos raišką aukštojoje mokykloje.

Empirinio tyrimo metu buvo taikoma tyrimo metodų trianguliacija, kokybiniai ir kiekybiniai tyrimo metodai. Apklausa raštu buvo stengiamasi išsiaiškinti bendresnes tyrimo dalyvių nuostatas ir tendencijas. Taikant interviu metodą siekta nustatyti sportinės identifikacijos turinį ir raiškos specifiką.

Tyrimo rezultatai reikšmingi aukštosios mokyklos dėstytojams, kurie rūpinasi, kaip skatinti studentų tobulėjimą jiems dalyvaujant sportinėje veikloje. Sportinės studentų identifikacijos sąsajos su aukštosios mokyklos aplinkos veiksniais parodo esamą sporto kultūrą, kuri turi įtakos studijoms Akademijoje. Sporto kultūrą studentai patiria visą laiką savo varžybinėje, studijų ir asmeninio tobulėjimo veikloje. Aukštosios mokyklos aplinkoje sporto kultūros tarpininkai būna draugai, treneriai, varžovai, teisėjai. Kai kuriais atvejais sporto kultūra ugdo studentų teigiamus jausmus studijų procese ir skatina stengtis.

Tyrimo rezultatai leidžia daryti išvadą, kad sportinę studentų identifikaciją lemia studentų aktyvumas sportinėje veikloje, jų sportiniai siekiai ir planai, sąlygų sportuoti aukštojoje mokykloje įvertinimas, savo sportinės veiklos suvokimas. Sporto kultūra aukštojoje mokykloje yra ir būtina palankios sportinės identifikacijos sąlyga, ir jos rezultatas. Tyrimas atskleidė sportinės identifikacijos raiškos sąsajas su tiriamųjų lytimi, studijų pasiekimais, akademine identifikacija, profesine identifikacija, gyvenamąja vieta ir tuo, kaip studentai jaučiasi aukštojoje mokykloje, kaip ją vertina.

Raktažodžiai: sportinė identifikacija, sporto kultūra, aukštoji mokykla.

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ON-LINE AND OFF-LINE ECG AND MOTION ACTIVITY MONITORING SYSTEM FOR ATHLETES

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ABSTRACT

The aim of this paper is to present a new ECG and motion activity monitoring and on-line analysis system for athletes. The developed system is intended to facilitate the coach in optimizing and individualizing the training of elite athletes.

The hardware system consists of the device for registration of ECG and accelerometer signals and wireless transmission to computer. The coach software works in two modes: on-line version is used during training and off-line version is designed for detailed data analysis after training. The new method for respiration frequency evaluation was developed and checked on 28 persons, and in most cases the developed algorithm correctly evaluated the respiration frequency of the investigated persons. The evaluation of athlete's functional state from calculated and measured parameters and formation of warning signals (green — normal state, yellow — limitary state and red — premonitory state) is based on the analysis applying Moore and Mealy automata algorithms. The software for the evaluation of the patient's activity was tested on 11 healthy students: the increase in physical activity level during the brisk walk was 1.4 times higher compared to the level during the slow walk, and during the jogging sessions it was 1.89 times higher than during the slow walk.

The results obtained during the investigations show that the developed ECG and motion activity monitoring system with two packages of software allows to measure cardio respiratory changes and changes in intensities of physical activity under daily conditions. The comprehensive off-line analysis by monitoring data provides the possibility for coaches to make more detailed analysis of cardio respiratory changes and changes in intensities during training.

Keywords: *monitoring system for athletes, electrocardiogram, accelerometry, respiration frequency.*

INTRODUCTION

The coach should seek to be a facilitator rather than a director during the training process; he is also responsible for the consideration of the possible outcomes (e. g. injury, overtraining, stress) that might arise due to incorrect training program (Cross, 1999). In order to improve training and coaching performance by individualization of activity there is a need for information technology that could monitor and provide feedback on physiological parameters.

Researchers were interested in increasing the performance of sportspeople by logging the results during training, on-line or off-line analysis and presentation of the analysis results to the coach and athletes, preventing injuries during rehabilitation of sportspeople (Glaros et al., 2002). However, the amount of information they provide is not enough for the coach. Usually only one physiological parameter, i. e. the heart rate (HR) is measured. The physiological parameters are needed for functional state evaluation of a sportsman or sportswoman for optimising his or her performance during the training process (Vainoras, 2002; Kellerman, 2006; Poderys, 2006). The aim of this study was to develop the monitoring system for monitoring cardio respiratory changes during sports training lessons and daily living activities and executing on-line and off-line data analysis. This study was the part of EUREKA project HEART GUARD (Korsakas et al., 2006). The main task of this project was to develop the personal wireless ECG and motion activity device and warning system for long term monitoring of home care patients or sportspeople.

METHODS

System architecture. The system architecture design includes the definition of system components and implementation requirements, specification of requirements for each unit, specification of interactions inside the system including data transfer standards. The architecture of ECG and motion activity monitoring system is presented in Figure 1. It consists of wireless ECG and accelerometer signals registration and transmission device (Fig. 2), computer and two packages of software. The first software package is intended for on-line analysis of vital signals and the second one — for comprehensive off-line analysis of stored data about athletes during monitoring.

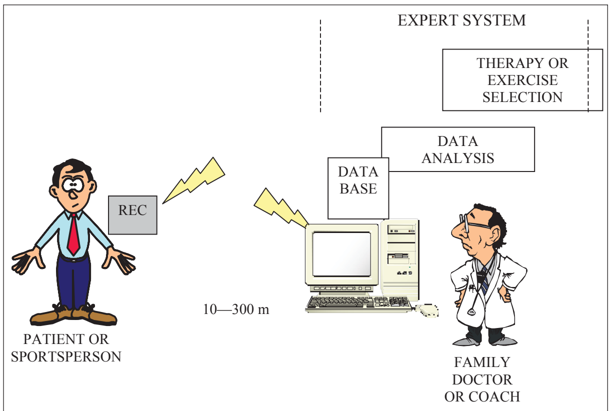


Figure 1. **The architecture of ECG and motion activity monitoring system**

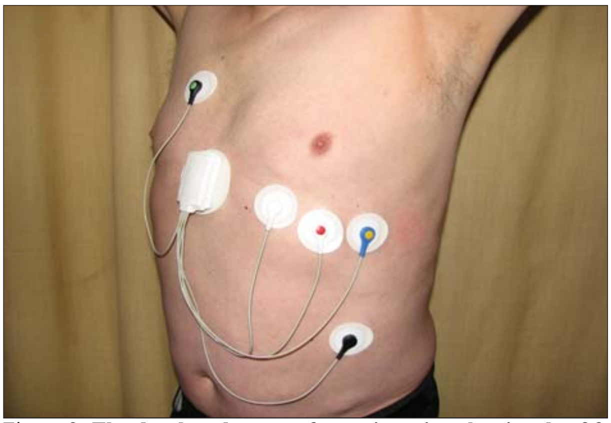


Figure 2. **The developed system for registration the signals of 3 ECG leads and 3-axis accelerometer (inside of box)**

A new ECG system consisting of five electrodes and three ECG leads has been proposed (Fig. 2): the first electrode is placed in the position of standard lead V1, the second one — V 4, the third one — V 5, the fourth — V 6, and the fifth electrode is placed bellow the chest.

Algorithm for evaluation of monitoring parameters. We described the data stream during monitoring using the convolution of Moore and Mealy automata (Berskiene et al., 2005). The data from ECG, respiration and motion parameters were obtained and evaluated by Mealy (M_l) automaton, later they were analyzed by Moore automata (M_r).

Calculation of breathing frequency from the ECG data. It is important to have as much information from the processes which could be recorded in simple noninvasive way as possible. An ECG is such a process, and in spite of the fact that ECG seems much investigated, the investigators in many countries are looking for new information on ECG. One attempt was to find methods for the evaluation of the function of lungs according to ECG changes that were influenced by respiration. It is well known that during the deep breathing frequency of the heart rhythm increases in the inspiration phase and decreases in the expiration phase. It means that HR is influenced by the regulatory systems and directly-through the changing pressure in breast. It seems that evaluation of breathing according HR change is rather a simple task, but unfortunately, it is rarely used in clinical practice. The reason of such situation could be explained by the relation of heart rhythm variability on the frequency of the heart, i. e. the increasing frequency causes the decrease of dispersion.

Twenty eight female athletes (22.6 ± 0.43 years old), involved in aerobics exercise program (2—3 times per week for 1.5 years) participated in the study. Personal monitor was fixed on each subject' s breast and all data were being recorded for 24 hours. The measures of the evaluation of all day activities were taken in the morning, an hour after they woke up, in the evening, at about 7—8 p. m., and at night, about 2—3 a. m. (Fig. 4, upper curve).

RESULTS

The developed on-line analysis software package performs the following functions:

- input and visualization of vital signals from registration device on the PC via Bluetooth interface (Fig. 3, bottom curves);
- storage of input data on the PC for later comprehensive off-line analysis;
- detection of QRS complex, calculation of HR, measurement of QRS duration and ST wave values in all three ECG leads, visualization of calculated parameters on the PC screen (Fig. 3, upper part);
- evaluation of athlete's activity and detection of "person markers" from the accelerometer data (Fig. 7);
- calculation of respiration frequency from the ECG data (Fig. 6);
- evaluation of athlete's functional state from calculated and measured parameters using Moore and Mealy automata algorithm (Berskiene et al., 2005) and formation of warning signals (green, yellow, red) (Fig. 3, upper part);
- writing the final report of athlete's monitoring (Fig. 8).

The criteria for the evaluation of ECG data are presented in Table 1 and the criteria for respiration frequency and motion activity evaluation are shown in Table 2.

Figure 3 presents the sample of screenshot: a table of calculated parameters (upper part) and input data (bottom part). Column HR (heart rate) includes data, estimated from current RR interval and in dHR — the difference of HR (dHR), estimated from current and previous RR interval, and column Cmp (comparison) contains the estimation of dHR (S — the same, I — increased, D — decreased); the column DQrs the duration (in ms) of current QRS complex (DQrs), and in column dDQrs — the difference of duration between current and previous QRS complex (dDQrs), column Cmp — the estimation of dDQrs; column sST — the amplitude (in μV) of deviation of current ST-segment from baseline, column dsST — the difference in amplitude between the current and the previous ST-segment (dsST), and column Cmp — the estimation of dsST. The following three columns (BR, dBR, Cmp) present the results of estimation of breathing frequency (Bf), (times per minute), determined from ECG data. Then the next two columns (Acs, Cmp) indicate the patient's position (H — horizontal, V — vertical), determined by 3-axis accelerometer, as well as changes of this position (S — the same, A — arise, L — lie down). The last columns (M, dM, Cmp) show the results of the estimation of movement (M) intensity, determined from x, y, z accelerometer signals. Finally, column Time indicates the time of recorded signals. The degree of parameter changes is

Table 1. **The criteria for the evaluation of ECG parameters**

Indices		I = 1	2	3	4
For heart rate (HR)	b / min HR_i ΔHR	0—40 the same ± 25%	40—100 higher > 25%	100—140 less < 25%	140 and more
For QRS complex duration (DQRS)	ms $DQRS_i$ ΔDQRS	70—100 the same ± 20%	100—120 longer > 20%	120—140 shorter < 20%	
For ST-segment amplitude in any ECG	ST_i Σ / ST_i $\Delta\Sigma / ST_i$;	0—0.1 mv the same 0—0.1 mV	> 0.1 mV bigger > 0.1 mV	less < 0.1 mV	

Table 2. **The criteria for the evaluation of respiration frequency and motion activity data**

Indices		I = 1	2	3	4
Evaluation of breathing frequency (Bf)	Bf / min Bf_i ΔBf_i	0—6 the same ± 25%	6—10 higher > 25%	10—20 less < 25%	> 20
Motion activity processes (Acs)	Acs Acs_i	supine the same	upright stands up	urgent alarm lie-down	
Evaluation of movement (M)	M M_i	stationary the same	small higher	high less	

Figure 3. **The sample of screenshot: table of calculated parameters (upper part) and input data (bottom part), 3 ECG leads (upper curves) and 3 channel motion signals (bottom curves)**

Figure 4. **Dynamics of HR and R wave amplitude variability during 24 hours**

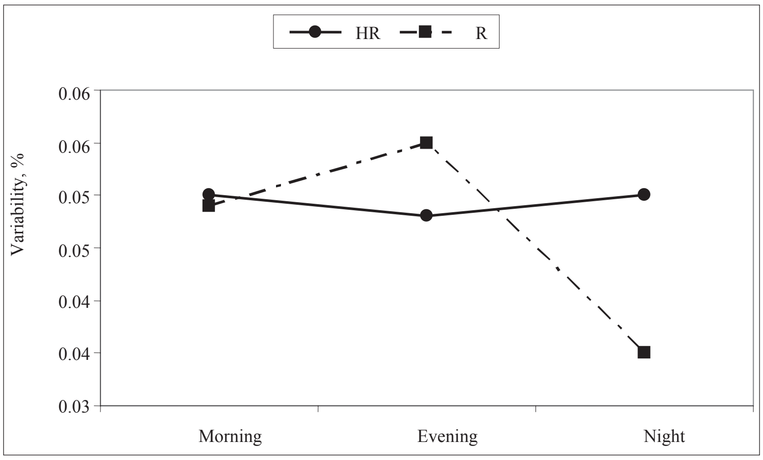
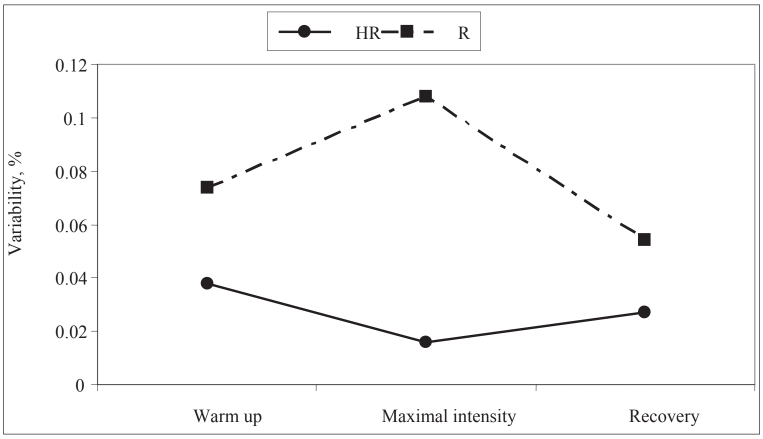


Figure 5. **Dynamics of HR and R wave amplitude variability during aerobic exercises**



indicated by different colors: green — normal, without any changes, yellow — limitary changes, red — great abnormal changes in parameters or functional state.

Input data (Figure 3, bottom) consist of three ECG leads D1, D2, D3 (fD1 = Φ1 – Φ2, D2 = Φ1 – Φ3, D3 = Φ1 – Φ4, where Φ1, Φ2, Φ3, Φ4 are potentials, recorded in 1, 2, 3 and 4 points) and 3 motion signals (the last three curves in the underside of Figure 3 represent the intensity of body movement in horizontal (x), vertical (y) or transversal (z) directions).

The real time software for personal monitor is created by using plain C^{++} and it can run on different PC platforms.

In the training session three points during the warm up, the maximal activity, and the recovery have also been taken (Fig. 4, bottom curve). It is easy to see that in the day time, when HR changes are not so meaningful, the changes of HR variabi-

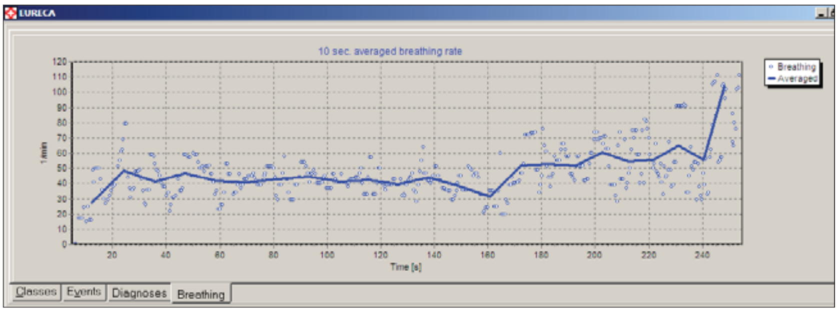


Figure 6. **Results of evaluation of respiration frequency from RR amplitudes**

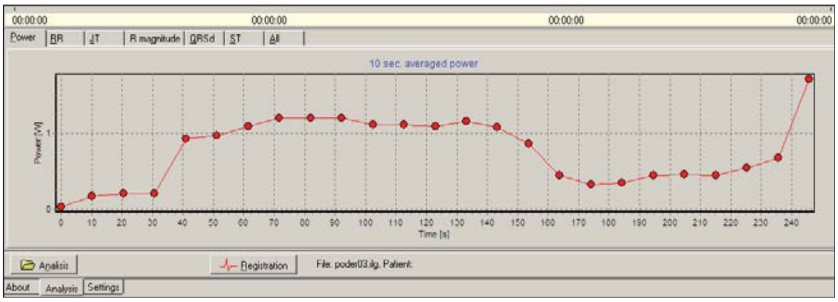


Figure7. **Results of evaluation of athlete's activity, developing power (W)**

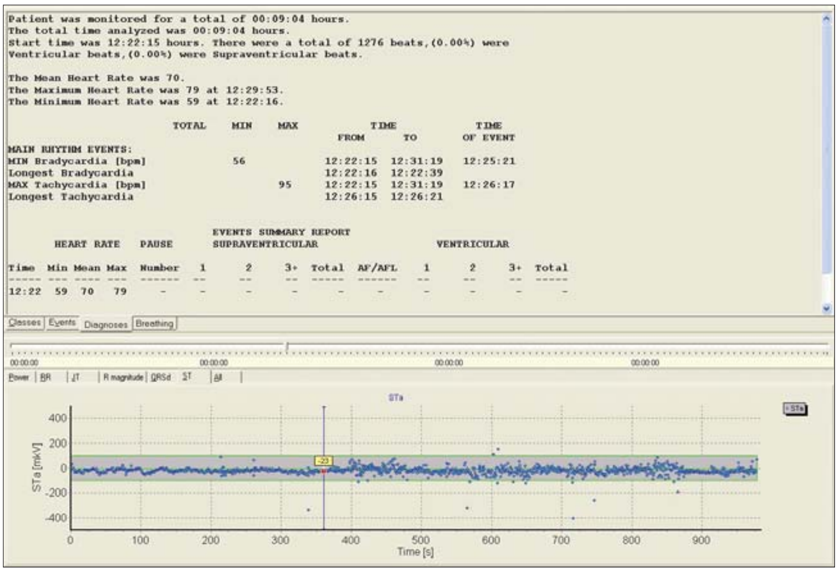


Figure 8. **Final report of athlete's monitoring**

lity (Va = SD / mean) are marginal also, but during aerobic fitness training the variability drops down significantly, and in this case the evaluation of breathing becomes problematic. Another problem is the disturbances of the heart rhythm, when the sequence of heart beats dramatically changes.

Seeking to increase the accuracy of the evaluation of the breathing frequency we have to find other means on ECG which could reflect the breathing process. A stroke volume is about 100 ml of blood during every beat. When a greater amount of blood flows to the lungs, the resistance of the breast decreases. ECG shows it as a change of R wave amplitude. An augmentation of load causes the increase of stroke volume, and the changes of R wave increase too. For the same students the changes of R amplitude in the same situations — during the day (Fig. 5, bottom curve) and during aerobic exercise (upper curve) were evaluated. As it was expected, during load the variability of R wave increased, which means that this parameter could improve the accuracy of the estimation of breathing.

According to the information obtained from individual detailed investigation of R wave amplitude changes, algorithm for calculations of breathing frequency was developed. The first step was to choose an interval in which the frequency would be calculated, for example, from 10 s to 30 s, the longer interval could lead to overlooking some sudden breathing problems. In the chosen interval the QRS complexes were detected and R wave amplitude, together with RR intervals (interval between two adjacent QRS complexes) were measured (Fig. 6 a). The mean value of R amplitude and RR interval were calculated. The ratio of individual parameter to the mean for every beat was calculated, too. With accuracy ε in the chosen interval the maximal and minimal values of R wave amplitude and RR intervals were detected. The intervals between the detected maximal and minimal values were calculated and the means of both were obtained. These mean values represent the frequency of breathing.

Off-line analysis of stored monitoring data. The on-line monitoring program always records ECG and motion activity data to PC hard disk. These data are intended for the analysis using mathematical and expert methods, and results are assigned for medical or coaching staff. For this purpose the off-line software for comprehensive analysis of stored person monitoring data was developed. The off-line software performs the following functions:

- recognition and measurement of ST-segment changes, JT interval duration, RR interval duration and visual representation in a time domain;
- using R wave's magnitudes and RR time interval sets, calculation of respiration frequency and presentation it in visual time domain format (Fig. 6);
- QRS complex detection and classification to determined classes;
- representation of monitoring data and events in time domain, selection of the event environment, measurement of magnitude and duration;
- calculation of set disperson of values of R an S wave's magnitude, relation of JT and RR time intervals and presentation of visual results in Poincare diagram and time domain format;
- determination of the patient's position (horizontal or vertical), evaluation of the patient's activity (Fig.7), and detection of "patient markers" from the accelerometer data;
- writing the final report of the patient's monitoring results (Fig. 8).

After the recognition of QRS complex its marks of onset and offset were defined, the measurement of QRS duration and determination shape was performed, and the classification of QRS to five classes was accomplished: normal beats (N), supraventricular beats (S), ventricular beats (V), fussion beats (F), pacemaker beats (Q), and unclassified complexes (U) formed the last group.

Figure 6 presents means of breathing frequency, detected from oscillations of R wave during inspiration and expiration. After 200 s from the beginning of the investigation the athletes were asked to breath frequently; the developed algorithm gave the correct result, and actual results matched the results obtained in the program.

The sample of results of the evaluation of the athlete's activity could be observed in Figure 7: till the fiftieth second of the investigation the athletes were resting, and after load was increased up to 450 W till the end of the investigation (400 s).

The beginning of the final repeat (Figure 8) gives the statistics of detected rhythmic disorders: the total monitoring time, the starting time of the investigation, the total number of recorded heart beats, and among them — the number of abnormal ventricular and supraventricular heart beats with ratio (in percent) to all beats. Then the maximal and minimal HR values are presented, and the results of detailed analysis of detected arrhythmic events are supplied. In the bottom part of Figure 8, the trend of ST-segment displacement (in μV) STa from baseline during the whole period of investigation can be observed.

The off-line software package is created using plain C++ and it works in the WINDOWS environment with the PC PENTIUM-IV 3 GHz processor about 5 sec for data record 1 hour duration and 6 channels by 500 Hz sampling rate. In the nearest future the developed personal monitor with patient functional state evaluation software will be tested according IEC 60601-2-47:2001 using standard data bases.

The investigations of respiration frequency (28 female students during their every day life for 24 h and during their aerobic fitness training) from ECG parameters during physical load showed the adequacy with real situation.

DISCUSSION

Many methods for the assessment of energy expenditure under daily living conditions, such as monitoring HR, or physical activity level measured by doubly labeled water and accelerometry, accelerometry combined with HR telemetry, portable global positioning units in complement with accelerometry were proposed (Hoos et al., 2003; Kumahara et al., 2004; Rodriguez et al., 2005). It was shown that a combination of HR and accelerometry as well as accelerometry alone could serve as a method for the assessment of energy expenditure during daily living activities (Kumahara et al., 2004; Karantonis et al., 2006). In the developed ECG and motion activity monitoring system, the proposed decision algorithm based on the convolution of Moore and Mealy automata and two packages of software on-line and off-line data analysis were implemented. The software for the evaluation of the patient's activity was tested on 11 healthy students with a mean age of 20.6 (S.D. 3.3) years by using the mobile device during the performance of activities of various intensities. The integration period was set at 10 s, and the final output was expressed as integrated physical activity level. The increase in physical activity level during the brisk walk was 1.40 ± 0.12 times higher as compared to the one during the slow walk (it corresponds to motion level 2 presented in Table 2), and during the jogging session it was 1.89 ± 0.14 times higher than during the slow walk (it corresponds to motion level 3 presented in Table 2).

Literature analysis shows an increasing interest in the application of information technologies in sports training (Vainoras, 2002; Kellerman, 2006; Poderys, 2006). The aim of the EUREKA project "*Mobile Personal ECG Monitor, HEART GUARD*" was to develop a new device for monitoring cardiovascular functioning under daily life conditions and to develop and implement the monitoring of physical activity into the system using accelerometers and wireless technologies of data transmission.

CONCLUSION

The results obtained during the investigations show that the developed ECG and motion activity monitoring system with two packages of software allows to measure cardio respiratory changes and changes in the intensities of physical activity during the training session and under daily living conditions.

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TIESIOGINĖS IR NETIESIOGINĖS SPORTININKŲ ELEKTROKARDIOGRAMOS IR JUDĖJIMO AKTYVUMO STEBĖSENOS SISTEMA

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SANTRAUKA

Tikslas — pristatyti naują tiesioginio ir netiesioginio sportininkų EKG ir judėjimo aktyvumo stebėsenos sistemą. Sukurtoji sistema yra skirta treneriams — elito sportininkų treniruotės vyksmui individualizuoti ir optimizuoti.

Sistemą sudaro techninė ir programinė įranga: techninę — EKG ir akcelerometrinių signalų registravimo ir bevielio perdavimo į kompiuterį įrenginys; programinę — du programų paketai: tiesioginės stebėsenos duomenų analizės treniruotės metu ir netiesioginės stebėsenos duomenų, sukauptų kompiuterio atmintyje, išsamios analizės po treniruotės.

Norint tiesioginės stebėsenos metu įvertinti sportininkų funkcinę būseną iš EKG parametrų, kvėpavimo dažnio ir judėjimo aktyvumo, buvo panaudotas Moore ir Mealy automatų algoritmas. Programą sudaro trijų tipų signalai, informuojantys apie sportininko būseną: žalia spalva — normali, geltona — ribinė, raudona — grėsminga. Sukurtas naujas kvėpavimo dažnio įvertinimo metodas ir patikrintas testuojant 28 sportininkus aerobikos pratybų metu. Daugeliu atvejų sukurtoji programa sportininkų kvėpavimo dažnį įvertino tiksliai. Sportininkų judėjimo aktyvumo vertinimo programa patikrinta vienuolikai studentų einant, bėgant ir atliekant šuolius.

Gauti rezultatai atskleidė, kad fizinio aktyvumo lygis bėgimo metu buvo aukštesnis 1,4 karto ir 1,89 karto — atliekant šuolius, palyginti su lėtu ėjimu. Sukurtosios sistemos ir kvėpavimo dažnio įvertinimo preliminarūs testavimo rezultatai parodė, kad tiesioginio EKG ir judėjimo aktyvumo stebėsenos sistema gali būti panaudota sportininkų būsenai stebėti treniruočių metu, o išsami stebėsenos duomenų analizė po treniruotės leis treneriui tiksliau įvertinti judėjimo užduočių atlikimo kokybę taip pat širdies ir kraujagyslių, kvėpavimo sistemų funkcijos kitimą per pratybas.

Raktažodžiai: sportininkų stebėsenos sistema, elektrokardiograma, akcelerometrija, kvėpavimo dažnis.

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LINEAR AND NONLINEAR ANALYSIS OF THE TRADITIONAL AND DIFFERENTIAL STRENGTH TRAINING

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ABSTRACT

Training methods are commonly studied using lineal and quantitative research, limiting the possibilities to proof new ways of optimizing the training process. The aim of the study was to compare the classical strength training approach, based on repetitions, with differential training for the improvement of difficulty elements in aerobic gymnastics applying a linear and a nonlinear tool for analyzing the interaction between load and performance.

Two female national standard aerobic gymnasts followed three periods of training (TTa: 5 weeks of traditional training; DT: 8 weeks of differential training; TTb: 5 weeks of traditional training). Load applied to the gymnasts was expressed quantitatively (quantitative load) with an equation including time of execution (t), number of series (N), number of exercises in each series (Rp) and relative intensity, and qualitatively (qualitative load) defining the number of different exercises performed. Performance was defined through 6 tests based on the execution of three different push-ups. Quantitative and qualitative load, the time of execution of the push ups and the time of flight of the jumps were determined weekly during the 17 weeks. The interaction between the load applied to upper limbs and performance of push ups, and the interaction between the load applied to lower limbs and performance of jumps were analyzed using a non-linear metamodel (PerPot) and cross correlations.

Push ups results show that the increase in load quantified qualitatively correlates more positively with the increase in performance than with the increase in load measured quantitatively. This suggests that subjects respond better to an increase in the variation of training stimulus than to an increase in the number of repetitions. Nevertheless, PerPot proposes a reduction in the number of varied exercises in the DT period. Regarding jumping tests, the performance of both subjects remained constant, suggesting that four months of training was not enough to improve the time of flight in experienced gymnasts, or the training methods were not the most adequate.

This study suggests that (1) differential training seems to lead to a greater increase in performance than traditional training, but (2) the same results could be achieved by reducing the number of varied exercises or combining both approaches.

Keywords: *non-linear metamodel, qualitative load, performance.*

INTRODUCTION

The current training methods in many sports are strongly influenced by cybernetics and cognitive theories. The traditional approach of training assumes that the athlete has to know in advance the right or correct movement and try to reproduce it through repetition. The repetitions should provide a basis for creation of fixed responses in a form of motor programs, stereotypes or motor representations which should guide the adaptive behaviour of an athlete. This model is clearly evident in many individual sports, where the situations during competition are apparently always repeated, as in aerobic gymnastics. For many coaches, repetition of exercises is the way to achieve automation. However such relying on the fixed learned responses as a theoretical explanation can not account for the obvious flexibility of motor actions of expert sport performers. Dynamical systems theory gives an original perspective on how these, at first glance, contradictory characteristics of the expert performers, namely stability and flexibility, can be attained. New training proposals based on the concept of self-organisation and the individuality of motor actions emerge from this perspective.

The differential training approach (Schöllhorn, 1999) with a different understanding of variability in practice has been compared with traditional methods in many sports (Jaitner, Pfeiffer, 2003; Schönherr, Schöllhorn, 2003; Trockel, Schöllhorn, 2003). Differential training attempts to learn from differences of the motor patterns and claims to prepare the athlete to adapt better to new situations in a shorter time. It can offer a new way of generating changes in coordination, modifying the intrinsic dynamics of the system and providing a new set of experiences for discovering the final response.

The new approaches claim for alternative methods and tools able to capture the qualitative changes produced in motor actions. The nonlinear dynamics framework offers the chance to study such changes and allows the emergence of new ways of optimizing the training process.

The scarce available literature in aerobic gymnastics analyse the muscular and metabolic demands of the sport (Torrents et al., 1999; López et al., 2002) concluding that maximum and mainly explosive strength are the main conditional capacities. Different authors have observed that repetition of analytic exercises is the main approach used to improve performance (Torrents, Balagué, 2001; Gutiérrez, 2002).

In order to study the possibilities of differential training applied to aerobic gymnastics, we analyze the interaction between load and performance, using a linear tool of analysis and a nonlinear one, the PerPot metamodel (Perl, 2001, 2004), as well as a quantitative and a qualitative way to measure the load applied to the athletes.

The aim of the study was a) to compare the classical approach, based on repetitions, with differential training for the improvement of specific difficulty elements of aerobic gymnastics in which muscular strength is a determinant factor; and b) to observe the differences of a linear and a nonlinear tool for analyzing the interaction between load and performance using two different ways of quantifying load.

MATERIAL AND METHODS

Subjects. Two female gymnasts of national standard, 20 (52 kg; 1.53 m) and 21 years old (55 kg; 1.60 m) took part in the study and were measured daily during a period of 18 weeks. Accurate control of load and performance parameters was carried out for the case study.

Procedures. *Training protocol.* The gymnasts trained for 3 hours a day, 6 times a week. Each session was divided in two groups of strength exercises: upper body exercises (related to push-ups) and lower body exercises (related to jumps).

The full training period was divided into 3 sub-periods:

1) 5 weeks of traditional training (TTa), based on high number of repetitions of the same exercises oriented towards getting the correct technique;
2) 8 weeks of differential training (DT) based on varied exercises, as has been already described;
3) 5 weeks of traditional training (TTb), similar to the 1st sub-period.

The load was determined weekly during the whole training period to study its interaction with performance. It was calculated in two ways:

- "Quantitative load" was defined by equation 1, including time of execution (t), number of series (N), number of exercises in each series (Rp) and relative intensity (Irel: percentage of maximum strength and normative scales based on subjective judgment rules -FIG, 2004):

$$L = \frac{N.Rp.Irel}{t} \quad \text{Equation 1}$$

- "Qualitative load" is defined as the number of different exercises performed.

Testing protocols. Performance was evaluated weekly by means of 6 tests (3 of them evaluating the upper body strength with one-arm push-ups and 3 evaluating the lower body strength with jumps):

- One-arm push-ups: performed with the right arm, with the left arm and hinge push-ups. The positions and the required degrees of bending were previously fixed to define valid trials. Subjects had 4 sec to perform a complete push-up and they were asked to do it as fast as possible. The absolute time of execution (flexion and extension movement until recovering the starting position) was evaluated. As the decrease in the execution time will correspond to an increase in the performance, -4 was added to the result of each test to make lower values correspond to worse performance and higher values to better performance.

- Jumps: Leap jump (jump performing a split — sagittal plane — in the air), straddle jump (jump opening legs in the frontal plane) and half turn straddle jump (straddle jump performed after turning 180º in the air), respecting technical requirements, were performed. Subjects stood off the platform and made a falling step with feet together on to the platform. They had then to perform the jump falling with both feet together and at the same time. The flight time of each jump was measured. One gymnast performed only the leap jump because of choreography requirements.

After a standardized 20 min warm-up, the gymnasts repeated each test three times and the best of them was chosen for the analysis.

A Dynascan-IBV 7.0 force platform was used for collecting the force applied at 500 Hz from one arm in the push-ups and from both legs during the jump movements. The sessions were recorded with an 8 mm video camera.

Data analysis. The PerPot metamodel version 4 was used to study the non-linear interaction between the load and performance. The basic concept of the PerPot metamodel is that of antagonism: each load impulse feeds a strain potential as well as a response potential. These buffer potentials in turn influence the performance potential, where the response potential raises the performance potential and the strain potential reduces the performance potential with a certain delay. The relation between the delays specifies the performance profile. As potential capacities are limited, potential overflows can occur and a reserve profile (difference between strain potential capacity and current strain level) is defined, indicating how close the body is to collapse.

To introduce the load and performance data into the Perpot metamodel, it is normalized to a maximum of 1.

Cross correlations were also calculated to determine delayed effects between the load and performance.

RESULTS

One-arm push-ups. Table 1 shows the mean value of the quantitative and qualitative load and the differences between the initial and final performance test values for the push-ups in the 3 training sub-periods in both subjects.

The quantitative load decreased by 22% (subject 1) and by 17% (subject 2) between the TTa and DT sub-periods and by 19% and 21%, respectively between the DT and TTb sub-periods. In contrast, qualitative load increased by 82% and 79%, respectively, between the TTa and DT sub-periods and decreases by 87% and 82%, respectively, between the DT and TTb sub-periods.

Subject 1's performance increased during the TTa sub-period, evaluated by means of the right-arm and hinge push-ups (0.34 and 0.562 sec, respectively), and decreased in the left-arm test (0.19 sec). During the DT sub-period, it increased by 0.56, 0.403 and 0.44 sec in right-arm, left-arm and hinge push-up, respectively in all tests and remained rather constant during the TTb sub-period.

Subject 2's performance decreased in the TTa sub-period (0.18, 0.133 and 0.228 sec respectively for the three push-up tests), increased in the DT sub-period for the push-ups with right and left arm (0.306 and 0.52 sec, respectively), while it reduced slightly in the hinge push-up test (0.027 sec). In the TTb sub-period, it increased in the left-arm and hinge push-ups (0.447 and 0.266 sec, respectively) while in the right-arm push-up it remained rather constant.

Both subjects' performance improved more in the DT sub-period than in TTa and TTb.

Subject 1

Periods	Mean QtL	Mean QlL	It-ft RP (s)	It-ft LP (s)	It-ft HP (s)
TTa	2.44	27	0.34	–0.19	0.562
DT	1.9	150.25	0.56	0.403	0.44
TTb	1.53	19.2	–0.12	0.046	–0.093

Subject 2

Periods	Mean QtL	Mean QlL	It-ft RP (s)	It-ft LP (s)	It-ft HP (s)
TTa	2.37	25	–0.18	–0.133	–0.228
DT	1.96	122.75	0.306	0.52	–0.027
TTb	1.55	21.4	–0.068	0.447	0.266

Table 1. **Mean load for each sub-period and difference in performance between the first and the last push-up tests**

Note. Qtl — quantitative load; QlL — qualitative load; It-ft — result of performance in initial test — result of performance of final test; RP — right push-up; LP — left push-up; HP — hinge push-up; TTa — first period of traditional training; DT — period of differential training; TTb — second period of traditional training.

Fig. 1. Performance of right push-up and quantitative load interaction by means of Perpot Metamodel of Subject 1

File	Subject 1 RP QtL
Dev. Ori	5.06
Dev. Opt	0.46
$Load_{mean}$	1.85
Pef_{mean}	2.24
D strain	2.5
D resp	3.0

Note. RP: Right-arm push-up; QtL: Quantitative Load; Pef: performance; dev.ori: original deviation of data; dev.opt: deviation of optimized data; D strain: delay of strain; D resp: delay of response.

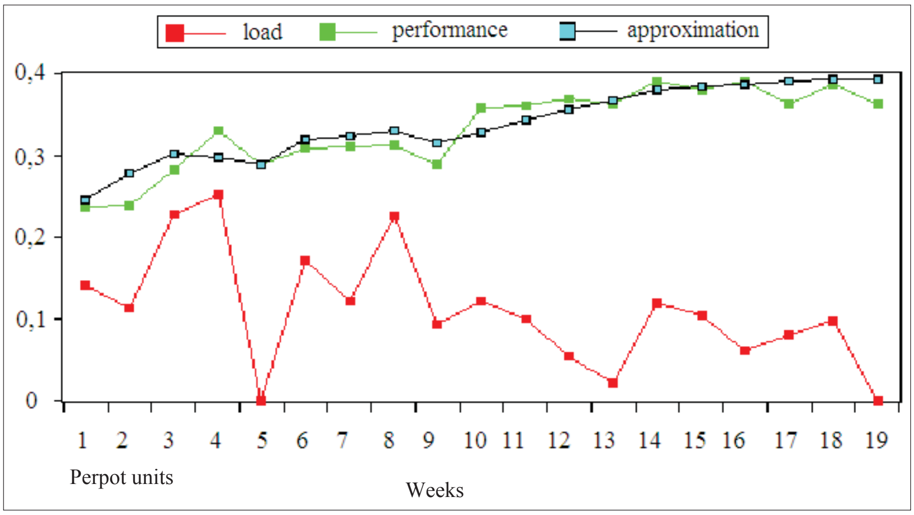
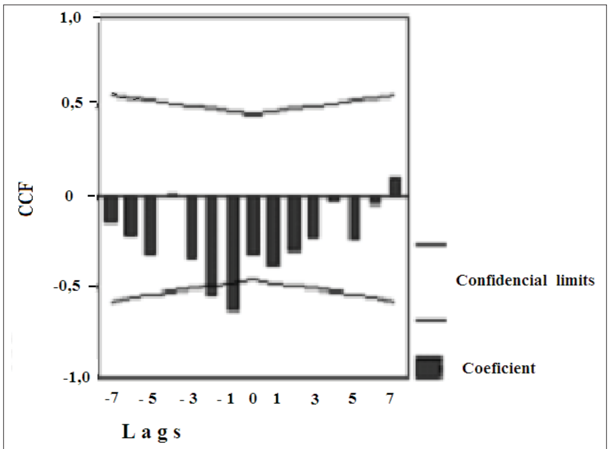


Fig. 2. **Cross correlations between quantitative load and performance of right push-up of Subject 1**



Note. CF: Correlation Coefficient.

These load-performance interaction results did not consider the delayed effects of load on performance. For this reason, the analyses using the PerPot metamodel and the cross correlation function were applied.

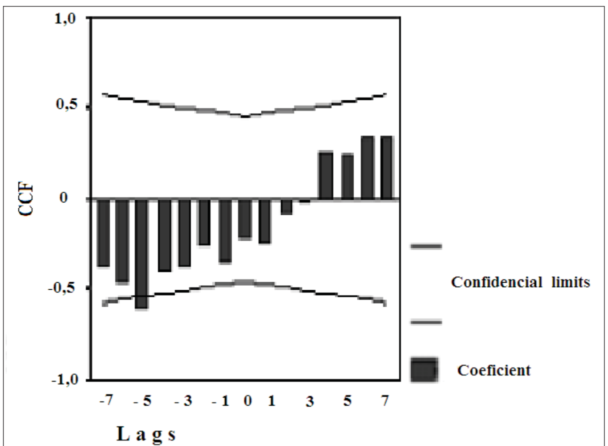
In Fig. 1, the relationship between the performance curve for the right-arm push-up and the quantitative load curve for Subject 1 is shown, using the PerPot metamodel. In Fig. 2, the same relationship is shown using the cross correlation analysis. It was observed that performance increased in the TTa and DT sub-periods, although there was a negative correlation with quantitative load. On the other hand, PerPot detected a positive relationship between delays, as the delay in response was greater than the delay in strain.

Fig. 3 and Fig. 4 show the relationship between qualitative load and performance using the PerPot metamodel and cross correlation analysis. PerPot detected a negative relationship between delays, as the strain delay was greater than the response delay.

Cross correlation analysis showed no significant positive correlation between qualitative load and performance.

Similar results using the PerPot Metamodel were obtained from data from one left-arm push-up and hinge push-up in the same subject. Nevertheless, hinge push-ups underwent a greater change, probably due to the worse initial execution level, as it was a new element for the subjects (see Fig. 5 and 6). Cross correlation analysis showed no significant results, either. Positive correlation occured only when qualitative load and performance correlated.

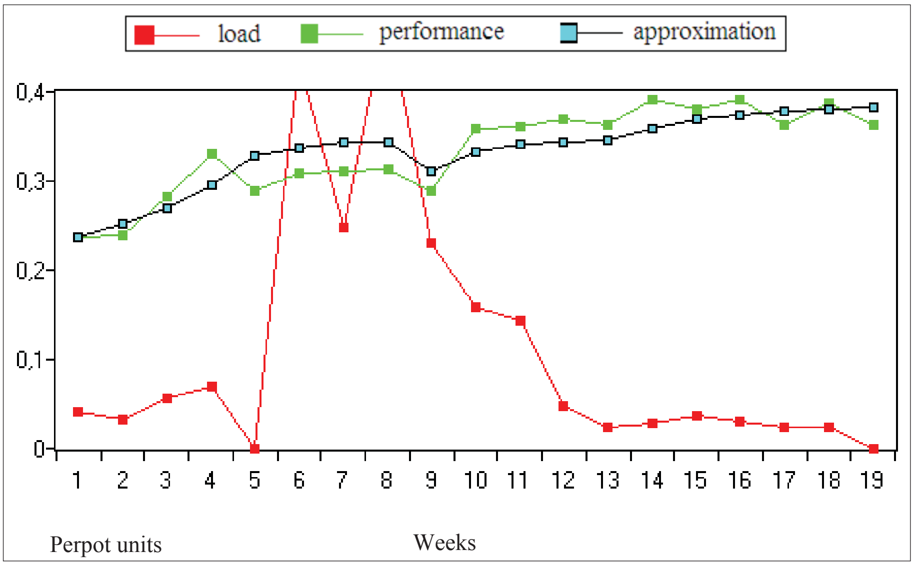
Fig. 4. **Cross correlations between qualitative load and performance of right push-up of Subject 1**



Note. CF: Correlation Coefficient.

The reserve profile showed similar behaviour in the three push-up exercises. It was positive when the quantitative load was used. On the other hand, an overflow was observed when using qu-

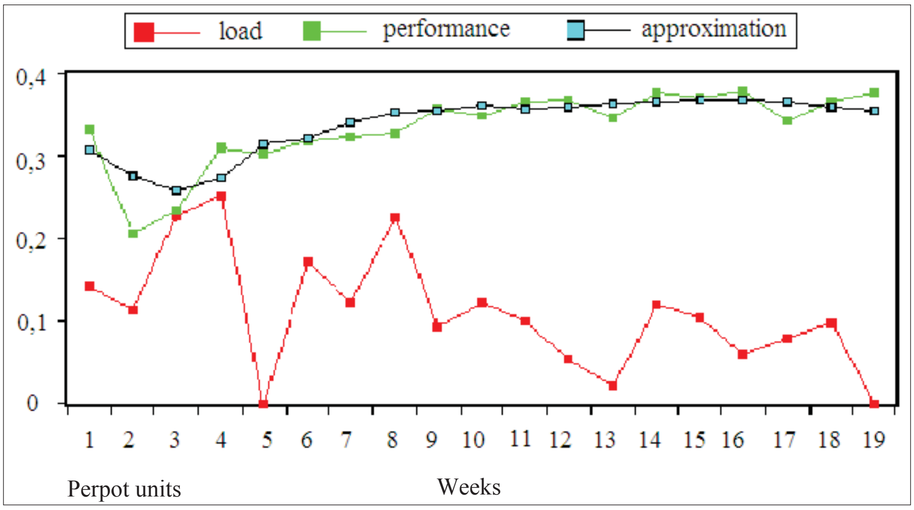
Fig. 3. **Performance of right push-up and qualitative load interaction by means of Perpot Metamodel of Subject 1**



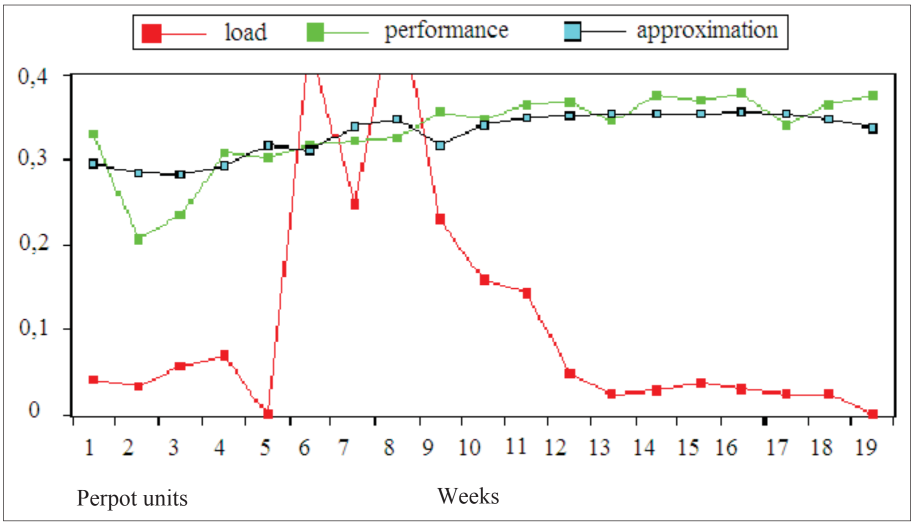
File	Subject 1 RP Q1L
Dev. Ori	6.44
Dev. Opt	1.64
$Load_{mean}$	75.42
Pef_{mean}	2.24
D strain	7.5
D resp	2.0

Note. RP: Right arm push-up; QlL: Qualitative Load; Pef: performance; dev.ori: original deviation of data; dev.opt: deviation of optimized data; D strain: delay of strain; D resp: delay of response.

Fig. 5. **Quantitative (upper graphs) and qualitative (lower graphs) load with performance of left arm push-up interaction by means of PerPot metamodel**



File	Subject 1 LP QtL
Dev. Ori	5.18
Dev. Opt	2.16
$Load_{mean}$	1.85
Pef_{mean}	2.29
D strain	3.5
D resp	6.0



File	Subject 1 LP Q1L
Dev. Ori	6.95
Dev. Opt	4.06
$Load_{mean}$	75.42
Pef_{mean}	2.29
D strain	9.5
D resp	2.0

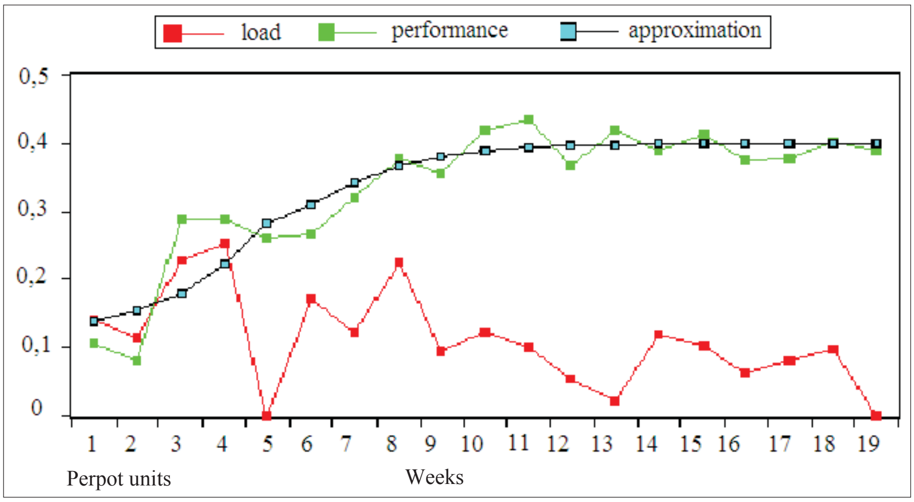
Note. LP: Left arm push-up; QtL: Quantitative Load; QlL: Qualitative Load; Pef: performance; dev.ori: original deviation of data; dev.opt: deviation of optimized data; D strain: delay of strain; D resp: delay of response.

alitative load, detecting a danger of overtraining. For this reason the PerPot metamodel proposed a reduction in qualitative load for the right arm push-up (46.9%) and for the left arm push-up (40.7%).

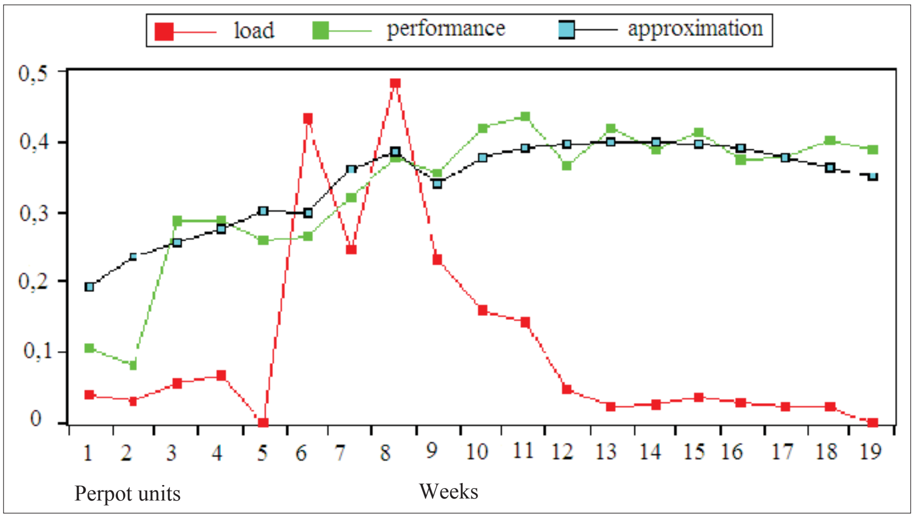
Table 2 summarizes the PerPot results for Su-

Fig. 6. Quantitative (upper graphs) and qualitative (down graphs) load with performance of hinge push-up interaction by means of PerPot metamodel

File	Subject 1 HP QtL
Dev. Ori	9.61
Dev. Opt	5.64
$Load_{mean}$	1.85
Pef_{mean}	1.20
D strain	4.0
D resp	6.0



File	Subject 1 HP Q1L
Dev. Ori	10.62
Dev. Opt	6.12
$Load_{mean}$	75.42
Pef_{mean}	1.2
D strain	7.5
D resp	2.0



Note. HP: Hinge push-up; QtL: Quantitative Load; QlL: Qualitative Load; Pef: performance; dev. ori: original deviation of data; dev. opt: deviation of optimized data; D strain: delay of strain; D resp: delay of response

Table 2. Summary of PerPot results of push-ups of Subject 2

	RP QtL	RP QlL	LP QtL	LP QlL	HP QtL	HP QlL
Mean Load	1.88	67.44	1.88	67.44	1.88	67.44
Mean Performance	2.31	2.31	2.24	2.24	1.42	1.42
Delay of Strain	4	7	1.5	6.5	4.5	5.5
Delay of Response	7.5	2	1	2	8.5	2

Note. RP QtL — right push-up and quantitative load; RP QlL — right push-up and qualitative load; LP QtL — Left push-up and quantitative load; LP QlL — Left push-up and qualitative load; HP QtL — hinge push-up and quantitative load; HP QlL — Hinge push-up and qualitative load.

bject 2. Similar relationships as in Subject 1 were observed between time delays. In this case PerPot also proposed a reduction in qualitative load in the right arm (45.5%) and left arm (18%) push-ups.

Cross correlation analysis indicated similar behaviour for Subject 1; positive but not significant correlations was found only between performance and qualitative load.

Jumps. Table 3 shows the mean quantitative and qualitative load values and performance values for each sub-period in both subjects for jumping tests. Performance had not changed significantly in the 18 weeks of training despite the changes in load in the different sub-periods.

Table 4 summarizes the results for both subjects concerning interactions between load and performance using the PerPot metamodel. No significant result is obtained applying cross correlation analysis.

DISCUSSION

Two subjects were studied following a single-subject analysis design to compare the effectiveness of differential training with traditional training (Bates et al., 2004). This type of study, besides offering complete information about the gymnasts' responses, fits better with the principles of dynamic

Table 3. Mean load for each sub-period and difference of performance between the first and the last jumping test for both subjects

Subject 1

Periods	Mean Qtl	Mean QlL	It-ft LJ (s)
TTa	2.114	26.8	0
DT	1.184	45.500	–0.016
TTb	0.523	19.8	–0.006

Subject 2

Periods	Mean QtL	Mean QlL	It-ft LJ (s)	It-ft SJ (s)	It-ft HSJ (s)
TTa	2.69	30.4	–0.028	–0.027	0
DT	1.310	69.250	–0.030	–0.090	–0.040
TTb	0.505	18.2	–0.026	–0.023	–0.006

Note. Qtl — quantitative load; QlL — qualitative load; It-ft — result of performance of initial test — result of performance of final test; LJ — Leap jump; SJ — Straddle jump; HSJ — Half-turn straddle jump; TTa — first period of traditional training; DT — period of differential training; TTb — second period of traditional training.

Table 4. **Summary of PerPot jumping results for both subjects**

Subject 1

	LJ QtL	LJ QlL
Mean Load	1.26	28.3
Mean Performance	0.55	0.55
Delay of Strain	3	7.5
Delay of Response	6	2

Subject 2

	LJ QtL	LJ QlL	SJ QtL	SJ QlL	HSJ QtL	HSJ QlL
Mean Load	1.47	44.58	1.47	44.58	1.47	44.58
Mean Performance	0.55	0.55	0.58	0.58	0.54	0.54
Delay of Strain	3	2.5	3	3	7	4
Delay of Response	6	5	6	6	2	7.5

Note. LJ QtL — Leap jump and quantitative load; LJ QlL — Leap jump and qualitative load; SJ QtL — Straddle jump and quantitative load; SJ QtL — Straddle jump and qualitative load; HSJ Qtl — Half turn straddle jump and quantitative load; HSJ QlL — Half turn straddle jump and qualitative load.

systems theory than the classical experimental models. The individual adaptive response to training, the dependency on initial conditions and the constant interaction of the gymnasts with the environment are better respected in a single-subject analysis design, rather than averaging data among a sample (Stergiou, 2004) and misrepresenting individual time series (Bouffard, 1993). Moreover, we have replicated the study over two subjects, observing surprising similarities in the behaviour of both of them. This can establish greater validity and generality for results, at least with a population of similar characteristics to the two we have used.

According to the results, the second sub-period, corresponding to the differential training, shows greater improvements in performance evaluated by means of arm push-up tests in both subjects. These results are especially notable in Subject 1, who had worse results in the initial tests. During this DT period, the quantitative load, calculated by the equation quoted including parameters of volume and intensity, decreased, while qualitative load, expressed by the number of different exercises, increased.

The high variability observed when comparing the results of each test session during all the training periods suggests the need to use periodic tests and the analysis of time series instead of the classical comparison between initial and final tests.

Considering these results, we can conclude that the differential training method produces greater increases in performance than the classical strength training method based on repetition of the same movements. Similar results have been found comparing the differential training and learning approach with traditional methods in groups of subjects (Jaitner, Pfeiffer, 2003; Schönherr, Schöllhorn, 2003; Trockel, Schöllhorn, 2003). However, these results do not take into account the delayed effects of load on performance, the duration of the different periods, and the natural physiological adaptation processes of the body, presenting delays in response.

The relationship between load and performance using the same data is also analyzed by means of the PerPot metamodel. PerPot detects a better relationship between quantitative load and performance than between qualitative load and performance. Overall, it considers that the quantitative load has been adequate for both subjects. In contrast, it considers that the amount of variations has been excessive and proposes a reduction in the number of variations to prevent overtraining. This response is probably due to the great difference between the numbers of variations proposed in the period of differential training compared to the other two periods of traditional training (TTa: 27, DT: 150,25 and TTb: 19, 2 weekly variations for Subject 1; TTa:

25, DT: 122,75 and TTb: 21,4 weekly variations for Subject 2). Although greater improvements have been observed in the differential training period, the PerPot indicates that a reduction in the load would allow similar or greater results, preventing overtraining. Overtraining occurs when the capacity of the subject to adapt is exceeded (McKenzie, 1999). For this reason the PerPot detects that qualitative load produces a delay of strain compared to the delay of response. This result did not appear in other studies using the PerPot, probably because load was only evaluated quantitatively (Mester et al., 2000). These results would suggest that an excess of coordinative demands can bring the subject to a state of overtraining.

The same data are also analyzed using cross correlations. In this case, the increase in quantitative load correlates negatively with the increase in performance in the three push-up tests and in both subjects. This analysis shows that the subjects' performance increases more when the training load decreases. In contrast, when load is evaluated qualitatively there are positive correlations between load and performance, showing that the increase in variations increases performance. The first subject shows positive correlations between qualitative load and performance, with a delay of three weeks in the right-arm push-up test and with any delay for the other two arm push-up exercises. Subject 2 shows a similar behaviour as Subject 1, and, despite the lower and non-significant correlations, it is observed that the positive correlation only appears when the load is considered qualitatively. A conclusion is that both subjects respond better to an increase in the variation of training stimulus than to an increase in the number of repetitions. It is important to point out that the load was the same in both forms, the only difference was the way of calculating it (quantitatively or qualitatively).

Regarding jumping tests, the performance of both subjects has remained constant. In Subject 2, a decrease in performance is even observed. This result obscures any clear conclusion about the comparison of both types of training or about the type of load quantification that correlates better with performance.

In beginners, four months of training are possibly enough to improve flight time significantly in all types of jumps. However, experienced gymnasts would probably need a different variable for measuring performance. It is possible that the athletes had already reached their limits, that the training applied has not been adequate or that the variable used for its evaluation (flight time) is not sensitive enough.

CONCLUSION

Differential training has led to a greater increase in performance in both subjects than traditional training based on repetitions. The increase in load quantified considering the number of variations correlates positively with the increase in performance, while the increase in load quantified through the volume and intensity of the exercises correlates negatively. It has also been observed that the different ways of quantifying load and the different analysis tools can affect the results of the study. The performance is rather variable over the whole period, suggesting that time series analysis is more useful than discrete tests. The number of variations proposed in this study has probably been excessive and same results could be reached by reducing the number of exercises or combining traditional and differential training during the second (DT) sub-period of the study. The effectiveness of this combined training should be further investigated; it would be especially interesting to know when it is more beneficial to apply each type of training. In this context, it would be very helpful to identify a sensitive variable providing information on the state of the athlete in relation to the stability of the process.

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TRADICINIO IR DIFERENCIJUOTO JĖGOS UGDYMO METODŲ ĮVERTINIMAS TIESINĖS IR NETIESINĖS ANALIZĖS BŪDAIS

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SANTRAUKA

Treniruotės metodų efektyvumui vertinti dažniausiai taikomi tiesinės ar kiekybinės analizės metodai, bet jie dažnai neleidžia atskleisti vertinamų treniruotės metodų naudingumo ir tikslingumo, sprendžiant treniruotės vyksmo optimizavimo problemas. Šios studijos tikslas buvo tiesinės ir netiesinės analizės metodais palyginti jėgos ugdymo efektyvumą taikant tradicinį jėgos ugdymo ciklą — parenkant tinkamą pratimo kartojimų kiekį ir diferencijuoto jėgos lavinimo metodą — didinant pratimo elementų sudėtingumą.

Dvi moterys, Ispanijos nacionalinės aerobikos rinktinės narės, atliko suplanuotus tris treniruotės mezociklus taikant šiuos metodus: TTa — penkių savaičių tradicinį jėgos lavinimo; DT — aštuonių savaičių diferencijuotą jėgos lavinimo; TTb — penkių savaičių tradicinį jėgos lavinimo. Per pratybas gimnasčių atliekamas krūvis buvo kiekybiškai išreiškiamas (kiekybinis krūvis) lygtimi, kartu įvertinant pratimų atlikimo trukmę (t), atliktų serijų skaičių (N), kiekvienos serijos pratimų skaičių (Rp) ir santykinį intensyvumą. Atliktas ir kokybinis vertinimas (kokybinis krūvis) nustatant skirtingų pratimų skaičių. Gimnasčių specialusis darbingumas buvo vertinamas atliekant šešis testus, kuriuos sudarė trys skirtingi atsispaudimai. Kiekybinis ir kokybinis treniruotės krūviai, atsispaudimų ir lėkimo fazės trukmė atliekant šuolius buvo registruojami kas savaitę (visas 17 savaičių). Ryšys tarp rankų ir pečių lanko raumenimis atlikto treniruotės krūvio ir atsispaudimų, tarp atlikto kojų raumenims treniruotės krūvio ir šuolių buvo tiriamas naudojant netiesinį metamodelį (PerPot) ir Kros-koreliacinės analizės metodą.

Atsispaudimų įverčiai parodė, kad kokybinis treniruotės krūvio didinimas reikšmingiau koreliavo su specialiojo darbingumo padidėjimu nei kiekybiškai išreikštas padidėjimas. Vadinasi, tirtų asmenų jėgos rodiklius daugiau veikia atliekamų pratimų įvairovė negu pratimo kartojimų kiekio didėjimas. PerPot rodo, kad tikslinga sumažinti atliekamų pratimų kiekį diferencijuoto jėgos ugdymo mezociklu. Tyrimo metu reikšmingai nepasikeitė abiejų tiriamųjų šoklumas, ir tai gali reikšti, kad šie keturi mėnesiai buvo per trumpas laikas arba kad taikyti treniruotės metodai nebuvo tinkamiausi.

Galima daryti išvadas: 1) taikant diferencijuoto jėgos ugdymo metodą labiau pagerėja specialusis darbingumas nei taikant tradicinį jėgos ugdymo metodą; 2) to paties rezultato galima pasiekti sumažinant atliekamų pratimų kiekį arba derinant abu metodus.

Raktažodžiai: netiesiniai metamodeliai, kiekybinis krūvis, darbingumas.

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IMPACT OF HYPERTHERMIA AND DEHYDRATION ON SKELETAL MUSCLE OF ADULT WOMEN PERFORMING ISOMETRIC EXERCISE OF MAXIMUM INTENSITY

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ABSTRACT

The aim of the study was to establish the impact of hyperthermia and dehydration on maximum voluntary contraction (MVC) force and central fatigue, as well as to assess the impact of rehydration on the function of skeletal muscle in conditions of hyperthermia when performing isometric exercise of maximum intensity for 2 minutes. The subjects were adult females (n = 8) not actively engaged in sports, aged 21.2 ± 2.4 years, body mass — 64.84 ± 8.4 kg and height — 170.8 ± 2.5 cm respectively.

Three studies were carried out: one control study and two experimental ones. During the first experiment the bodies of the participants in the study were subjected to hyperthermia and dehydration (the subjects sat immersed up to the pelvis in hot water (44 ± 1°C) bath for 45 min). During another experiment, the same methods of increasing hyperthermia being used, the bodies of the subjects experienced oral rehydration with 1000 ml NaCl 0.9% solution of 37°C.

*The MVC load lasted for 120 s (MVC-2 min) and every 15 s the muscle was stimulated by electrical impulses: the duration of the stimulation was 250 ms, the frequency — 100 Hz and the voltage — 85—105 V accordingly. We registered the movement of MVC (N * m) and the degree of voluntary activation of muscles according to the formula VA% = (MVF + electrical impulse) / MVF * 100. When the load was applied the subjects were motivated verbally and they were provided with the visual feedback of changes in force signals. After hyperthermia and dehydration was applied, the rectal body temperature increased from 37.48 ± 0.25 to 39.5 ± 0.23°C ($p < 0.001$), and the inner temperature of the muscle (3 cm deep) — from 36.91 ± 0.29 to 39.83 ± 0.31°C ($p < 0.001$) on the average. During the hyperthermia experiment the subjects had lost 0.4 ± 0.07 kg in weight on the average, and that was 0.62 ± 0.13% of their body mass. After oral rehydration in conditions of hyperthermia body mass of the subjects had increased by 0.48 ± 0.01 kg on the average, i. e. by 0.74 ± 0.08% of their body mass. Having analyzed the physiological index of heat stress (in the 10-point system) we have found that during both experiments the subjects had experienced a physiological stress of an extremely high level, e. g. in the case of hyperthermia — 8.85 ± 1.13 points and in the case of rehydration — 8.38 ± 0.98 points respectively. There was a significant decrease ($p < 0.001$) in MVC at the 3rd second of the load during both experimental researches and control research — at the 15th second of the load. These changes in MVC remained until the end of the 2nd min, compared to the indices registered before the load. During recovery, 5 min (A 300) after the load applied, MVC during control and experimental (hyperthermia) research had regained the level registered before the load ($p > 0.05$). Two-factor dispersion analysis revealed that the changes in the force in this case depended on time ($p < 0.001$), as well as on the body state ($p = 0.001$), whereas interaction of time and body state had no significant effect on the result ($p > 0.05$).*

After the analysis of the indices of voluntary activation we noticed that hyperthermia ($p < 0.05$) and rehydration ($p < 0.01$) had significantly increased the degree of voluntary activation (VA%), compared to the one established before the load. During the recovery time, 15 s after the load had been undertaken, the force index of voluntary activation regained the level that had been registered before the load. Two-factor dispersion analysis allowed us to establish that the changes in the force indices of voluntary activation depended on time ($p < 0.001$), the body state ($p = 0.047$) and the interaction between them ($p < 0.05$).

Applying the methods of passive muscle heating the participants in the study were subjected to hyperthermia and 1° dehydration. Hypertension increased the central fatigue. During the experiments of hyperthermia and dehydration MVC force fatigue altered homogeneously. In conditions of hyperthermia, rehydration had a negative impact on the central fatigue and increased it even more when maximum isometric load for 2 min had been undertaken.

Keywords: *hyperthermia, isometric exercise, dehydration, rehydration, central fatigue.*

INTRODUCTION

The ability of humans to perform physical exercise is directly dependent on fluctuation of the inner temperature in the body. Hyperthermia is a symptomatic increase in body temperature t° up to 38.2°C due to heat emission. With an increase in the core body temperature up to critical level (in the case of persons of average physical activity — 38.7 ± 0.2°C and in high performance athletes — 39.2 ± 0.1ºC) the human body becomes overheated and fatigue conditioned by voluntary efforts reveals itself; hydratation and adaptation to heat had no effect on this change though (Cheung, McLellan, 1998). Hyperthermia increases physiological body tension which can bring about considerable decrease in working capacity what leads to exhaustion, overheating, traumas and even death. Most animals cease physical activity until their core temperature reaches safety margin. A hypothesis has been constantly raised in special literature that dangerously high inner body temperature directly contributes to increasing fatigue and accelerating exhaustion. The latter problem has been given considerable attention lately though final solution, as to the essential mechanisms of the phenomenon has not been found yet (Morrison et al., 2004). It has been established that in conditions of hyperthermia physical working capacity decreases due to an increase in the core temperature up to a critical point (Cheung, McLellan, 1998), during which activation of thermoregulatory and cardiovascular systems takes place (Rowell, 1974). In conditions of hyperthermia there occur changes in periphery and there is an increase in muscle contraction and relaxation rate (De Ruiter, De Haan, 2000). Hyperthermia can directly affect voluntary activation of muscles, as temperature in the motor unit changes impulse frequency that is necessary to trigger tetanic contraction (Todd et al., 2004).

It had been considered for some time that the mechanism accounting for the neuromuscular fatigue during hyperthermia may have been due to both central and peripheral nervous systems (Kent-Braun, 1999). The research done by M. M. Thomas et al. (2006) has proved, however, that hyperthermia decreased the neuromuscular working capacity and this depended on the incapability of the central nervous system to fully activate the muscle, whereas periphery had no direct effect on the process.

Temperature homeostasis manifesting itself during hyperthermia increases perspiration and activated the work of the cardiovascular system (Armstrong, 2000). The reason due to which there may occur a decrease in the physical working capacity of the muscles is dehydration, i.e. loss of liquid from the body. It has been established that because of loss of 2% of body mass human endurance decreases by 22% and a loss of 4% in body mass calls forth a decrease in human endurance by as much as 48% (Armstrong et al., 1992). It has been found that working in hot climate conditions or performing long-term physical exercise of high intensity an individual loses 0.8—1.4 l of liquid in perspiration per hour on the average (Armstrong, 2000). The greatest volume of liquid lost in perspiration amounted to 3.7 l / h (Armstrong et al., 1986). It has been established that persons adapted to certain conditions alongside with liquid in the form of sweat lose about 0.8—2.0 g NaCl / l and not adapted ones — about 3.0—4.0 g NaCl / l respectively (Armstrong, 2000). The latter electrolytes are considered the main ones in the human organism that ensure the maintenance of water tonicity in intracellular and intercellular medium, nervous conductivity and cellular metabolism and due to which blood volume, i.e. osmotic pressure and regulation in the human body is maintained (Armstrong, 2000). It is known that the maximum volume of liquid that is possible to be assimilated by physically active individuals is about 0.8—1.2 l / h (Coyle, Hamilton, 1990).

We have not come across in special literature so far any data showing what thermal effect and degree of dehydration is experienced by women not actively engaged in sports applying the methods of passive muscle warming proposed by A. J. Sergeant (1987). We have not found any data either that would indicate in what way in the course of 45 min passively evoked hyperthermia and dehydration affects the functional capacity of human muscles. We have no clear picture as to the effect of hydration in conditions of hyperthermia when performing isometric physical exercise of maximum intensity either.

The aim of the study was to establish the impact of hyperthermia and dehydration on MVC force and central fatigue, as well as to assess the impact of rehydration on the function of skeletal muscle in conditions of hyperthermia when performing isometric exercise of maximum intensity for 2 min.

METHODS AND ORGANIZATION OF THE STUDY

The subjects were adult females (n = 8) not actively engaged in sports, aged 21.2 ± 2.4 years, body mass — 64.84 ± 8.4 kg and height — 170.8 ± 2.5 cm respectively. The subjects were acquainted with the aims of the study, its procedure and the possible discomfort. They confirmed in writing their consent to participate in the study.

The research has been done in accordance with the principles laid down in the Helsinki declaration of 1975 regarding the ethics of experiments with humans. The protocol of the research has been discussed and approved by the Kaunas Regional Ethics Committee of Biomedical Research (Protocol No 130/2005; Authorisation No BE–2–54).

Adjustment of dynamometer and posture. The isometric force of calf stretching muscles was assessed using the isokinetic dynamometer (Biodex Medical System 3. New York). The subjects were seated in the chair with dynamometer equipment and the right leg was tested. An extra calf-fixing device was attached to the dynamometer. The anatomic axis of the knee joint was established and equalized with the axis of the dynamometer. The whole amplitude of the knee joint (from 0º with the leg extended to the calf of the leg flexed at 115º angle) was established. To diminish the movements of the whole body caused by inertia the subjects were fixed with belts through shoulders, trunk and hips. The calf of the leg was fixed with a belt above the heel-bone knot at the lower third of the leg. The leg was fixed through the knee joint at the angle of 90º and 60º and it was weighted when it was fixed at the angle of 72º ± 5º (with gravity force in operation). On the control panel isometric regime was chosen. Registration of MVC force was done.

Logic of the experiment. Prior to the experiment a pilot study was undertaken during which the subjects were expected to get used to the laboratory environmental conditions and to learn how to undertake the load of voluntary isometric contraction of the highest intensity. No earlier than a week later the girls participated in either control or one of experimental tests chosen at random.

Three tests — one control and two experimental ones were performed. During control test the subjects after a non-intensive warming-up 10 min of running (pulse frequency — 110—130 beats / min) were seated in a special isokinetic dynamometer chair and were subjected to testing according to the same protocol, except for passive body warming.

Experimental test 1 differed from the control one in the sense that during it instead of warming-up hyperthermia was evoked passively. In experimental test 2 conducted using the same methods hyperthermia was evoked applying oral rehydration of the body having used 1 000 ml 37ºC (body temperature) of physiological NaCl 0.9% solution.

Applying the methods of passive warming the subjects having come to the laboratory used to sit still for 30 min in the room of usual temperature (20—22ºC). Then their rectal temperature was measured. Subsequently control MVC measuring was performed, i.e. three maximum voluntary muscle contractions extending the calf of the leg through the knee joint at the fixed 120º angle (muscle contraction duration — 5 s) with 2 min intervals between the contractions. Approximately at the 2nd—3rd second of these contractions *m. quadriceps femoris* was stimulated at 100 Hz frequency by a series of electrical impulses with the duration of 250 ms. Then passive leg warming was applied and immediately after warming rectal temperature was measured again. No later than 5 min after leaving the bath the subjects were seated in a special dynamometer chair where they performed (MVC-2 min). Control testing was applied 15 s and 300 s after the load undertaken. During the load the subjects wore warm long sports clothing, as well as a bath-room cap, to preserve hyperthermia during experimental test. To ensure hypothermia control, at the end of both experiments rectal temperature was measured.

MVC-2 min. Maximum voluntary isometric load was undertaken for 120 s. Percutaneous electrical stimulation of the femoral nerve using high voltage stimulator (*model MG 440, Medicor*, *Budapest, Hungary*) was performed every 15 s. The duration of stimulation was 250 ms, frequency — 100 Hz and voltage volume — 85—105 V respectively. Voltage volume was selected for each subject individually. Voltage of the electrical impulse was continuously increased until the involuntary muscle contraction force reached 70—75% of maximum force (duration of stimulation — 1 s, frequency — 100 Hz) (Nybo, Nielsen, 2001). Maximum voluntary force moment (N · m) and the degree level of muscle voluntary activation VA% = MVC + electrical impulse / MVC * 100 was registered. The smaller VA%, the greater central fatigue (100% shows full muscle activation). The subjects were motivated verbally during the load by providing them with visual feedback of changes in force signal.

Methods of passive warming. The subjects sat immersed up to the pelvis in hot water (44 ± 1ºC) bath for 45 min in room temperature of 20—22ºC. During warming the subjects could not make use of artificial cooling equipment. At the end of warming the temperature in the muscle 3 cm deep of the subject rises by ≈ 2.7ºC (Sargeant, 1987). Water temperature was measured by a hydrothermometer and room temperature — by a standard thermometer.

Methods of measuring inner muscle temperature. Inner muscle temperature was measured with the help of a needle thermometer (Ellab A / S, type DM 852, Denmark) before and after passive warming. After desinfesting the site of prick with 5% spirit-iodine solution the needle thermometer was inserted into the median third (3 cm deep) of the *m. vastus latarelis femoris* to the side of the femoral bone. Temperature registered in such muscle depth is considered mean temperature of the exercised muscle (Bloomstrand et al., 1984). After using the needle thermometer was sterilized in the autoclave (*M. O. COM Via delle Azlle 1, 20090 Buccinaso, Italy*). The duration of the process of sterilization — 30 min at temperature 121ºC.

Methods of measuring rectal temperature. Rectal temperature was measured with the help of a probe covered with silicone resin with a built-in thermosensing element (Ellab, type Rectal probe, Denmark). Before and after passive warming the subjects placed the probe with a thermosensing element into the rectum (time — 10 s, depth — 12 cm) (Proulx et al., 2003). After using the probe with a thermosensing element was sterilized in the autoclave.

Assessment of the cardiac and cardiovascular system. During passive warming heart rate (HR) was registered with the pulse measuring device "Polar 625x" (Finland) every 5 s.

Methods of measuring physiological stress index (FSI) of the heat. FSI was calculated according to the formula (Moran et al., 1998):

$$FSI = 5\,(T_{rectal\,t} - T_{rectal\,0}) \times (39.5 - T_{rectal\,0}) - 1 + (HR_t - HR_0) \times (180 - HR_0),$$

where $T_{rectal\,0}$ and HR_0 — basic measurings; $T_{rectal\,t}$ and HR_t — measurings repeated with time intervals.

Assessment of FSI — no stress or extremely low stress (0—2 points); low stress (3—4 points); medium stress (5—6 points); high stress (7—8 points) and extremely high stress (9—10 points).

Rehydration. It has been established that during hyperthermia the human body loses 0.8—1.4 l of sweat on the average, and 1 l of sweat contains from 0.8 to 4.0 g NaCl. The human body can assimilate about 0.8—1.2 l of liquid per hour (Armstrong et al., 1986; Armstrong, 2000). To restore the liquid lost 15 min before passive warming the subjects were given to drink physiological solution (0.9% NaCl) of 37ºC (body temperature). In the course of 60 min the subjects slowly drank up 1000 ml of liquid (100 ml every 6 min). Before and after passive warming the women the women were weighted on the electronic scales "Tanita TBF 300" (The USA). The difference in weight found showed the volume of liquid lost by the subjects.

Mathematical statistics. Arithmetical means and standard deviations of indices were calculated. Changes in neuromuscular indices depending on muscle temperature and alterations in time were analyzed applying two-factor dispersive analysis. The significance of difference between arithmetic means was established according to the bilateral Student's *t* criterion of independent samples. The difference was considered statistically significant when $p < 0.05$.

RESULTS

After evoking hyperthermia and dehydration the rectal body temperature of the subjects increased from 37.54 ± 0.24 to 39.62 ± 0.25ºC ($p < 0.001$), and after performing rehydration in conditions of hyperthermia the temperature rose

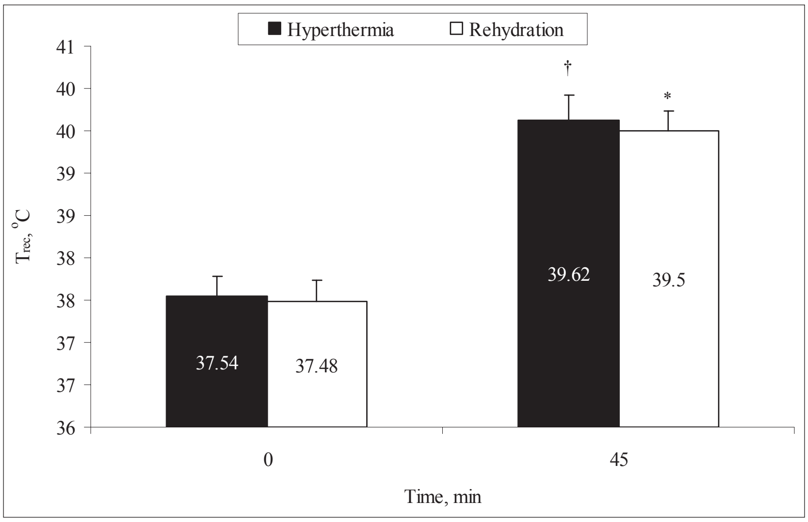
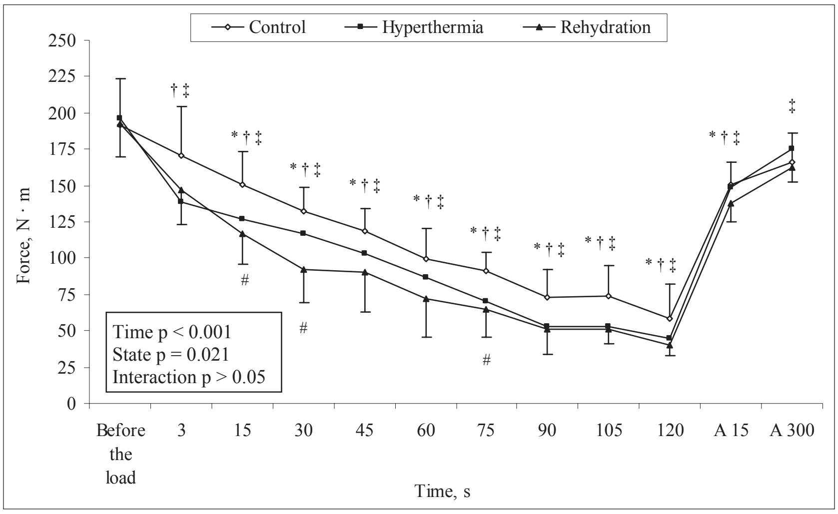


Fig. 1. **Indices of rectal temperature before and after passive warming**

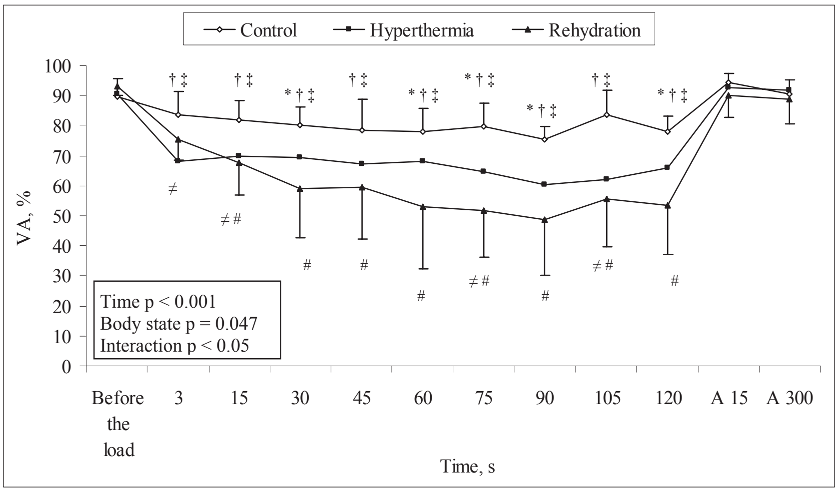
Note. †, * — change, compared to the basic value ($p < 0.05$).

Fig. 2. **Indices of maximum voluntary force performing (MVC) for 2 min extending the calf of the leg through the knee joint at the fixed 120º angle**



Note. # — difference between control and rehydration ($p < 0.05$); † — changes in hyperthermia indices, compared to basic ones / basic values ($p < 0.05$); ‡ — changes in rehydration indices, compared to basic ($p < 0.05$); * — changes in control values, compared to basic ($p < 0.05$).

Fig. 3. **Indices of voluntary activation performing (MVC) for 2 min extending the calf of the leg through the knee joint at the fixed 120º angle**



Note. # — difference between control and rehydration ($p < 0.05$); ≠ — difference between control and hyperthermia ($p < 0.05$); † — changes in hyperthermia indices, compared to basic ones / basic values ($p < 0\ 05$); ‡ — changes in rehydration indices, compared to basic ($p < 0.05$); * — changes in control values, compared to basic ($p < 0.05$).

from 37.48 ± 0.25 to 39.5 ± 0.23ºC ($p < 0.001$) on the average (Fig. 1).

During the hyperthermia experiment the subjects lost 0.4 ± 0.07 kg in weight on the average, and that was 0.62 ± 0.13% of their body mass. After oral rehydration in conditions of hyperthermia body mass of the subjects increased by 0.48 ± 0.01 kg on the average, i.e. by 0.74 ± 0.08% of their body mass. During the hyperthermia experiment the inner temperature of the muscle (3 cm deep) risen from 36.97 ± 0.28 to 39.96 ± 0.31ºC ($p < 0.001$) and after rehydration was applied — from 36.91 ± 0.29 to 39.83 ± 0.31ºC ($p < 0.001$) accordingly. Having analyzed the physiological index of heat stress (in the 10-point system) we found that during both experiments the subjects experienced a physiological stress of an extremely high level, e.g. in the case of hyperthermia — 8.85 ± 1.13 points and in the case of rehydration — 8.38 ± 0.98 points respectively.

There was a significant decrease ($p < 0.001$) in MVC at the 3rd s of the load during both experimental tests, and during control test — at the 15th second of the load. These changes in MVC remained until the end of the 2 nd min, compared to the indices registered before the load (Fig. 2).

During recovery, 5 min (A 300) after the load, MVC during control and experimental (hypothermia) tests had recovered to the index value registered before the load ($p > 0.05$). Two-factor dispersion analysis revealed that the changes in the force indices analyzed depended on time ($p < 0.001$) and on body state ($p = 0.021$), whereas interaction of time and body state had no significant effect on the result ($p > 0.05$).

After the analysis of the indices of voluntary activation we noticed that hyperthermia ($p < 0.05$) and rehydration ($p < 0.01$) had significantly increased the degree of voluntary activation (VA%), compared to the one established before the load (Fig. 3). It is of importance to note that during the rehydration experiment central fatigue had increased to a greater extent, compared with the hyperthermia experiment. This insignificant difference was established within the range of 30—120 s of MVC — 2 min ($p > 0.05$).

During recovery, 15 s (A 15) after the load, the degree of VA had recovered to the value registered before the load. Two-factor dispersion analysis revealed that the changes in the VA indices analyzed depended on time ($p < 0.001$), the body state ($p = 0.047$) and the interaction between them ($p < 0.05$).

DISCUSSION OF RESULTS

So far we have not come across any data in other research showing what thermal effect and degree of dehydration is experienced by women not actively engaged in sports applying the methods of passive muscle warming proposed by A. J. Sergeant (1987). Using similar methods we evoked hyperthermia and dehydration of the body during the hyperthermia experiment. The subjects lost 0.4 ± 0.07 kg in weight (0.62 ± 0.13% of their body mass), experienced a physiological stress of an extremely high level, the rectal body temperature rose from 37.54 ± 0.24 to 39.62 ± 0.25ºC ($p < 0.001$) on the average and the inner muscle temperature — from 36.97 ± 0.28 to 39.96 ± 0.31ºC ($p < 0.001$) respectively.

We have not found in special literature any data either that would indicate in what way in the course of 45 min passively evoked hyperthermia and dehydration affects the functional capacity of human muscles. It has been established that with an increase in the core body temperature up to 38.7ºC (in the case of persons of average physical activity) or to 39.2ºC (in the case of high performance athletes) the human body becomes overheated and fatigue conditioned by voluntary efforts reveals itself (Cheung, McLellan, 1998). We have found during the hyperthermia experiment that hyperthermia and dehydration had increased MVC fatigue performing MVC-2 min and evoked a higher degree of voluntary activation, i. e. central fatigue, compared to the data of the control test. We believe the extremely sudden rise in the core body temperature and dehydration of the body to have a significant effect on the final results of the research.

The scientists have been using different methods of passive warming and rehydration — the rectal temperature up to 39.5ºC was reached in 110 min and the subjects consumed some 1.4 l of liquid (Thomas et al., 2006). The effect of preliminary hydration in conditions of hyperthermia on MVC and central fatigue that is observed frequently performing isometric exercise of maximum intensity has not been clarified yet.

To restore the liquid lost during the rehydration experiment the subjects were given to drink physiological solution (0.9% NaCl) of 37ºC (body temperature). After performing oral rehydration in conditions of hyperthermia body mass of the subjects increased by 0.48 = 0.01 kg on the average and that made up 0.74 ± 0.08% of their body mass. This indicates that the subjects before MVC-2 min had fully rehydrated.

We have found during this experiment that preliminary hydration in conditions of hyperthermia had no effect on MVC fatigue and recovery, compared to the hyperthermia experiment. Still it had caused a higher degree of voluntary activation, i. e. central fatigue performing MVC-2 min. We believe that this may be partly dependent on the temperature (37ºC) of the physiological NaCl 0.9% solution, on the changes in biochemical mechanisms due to penetration of this solution into the system of blood circulation, as well as on the energy consumption for resorbtion of liquids. Due to oral rehydration the balance of natrium and potassium in intracellular and intercellular medium may have been subjected to changes. The latter electrolytes are considered the main ones in the human organism that ensure the maintenance of water tonicity in intracellular and intercellular medium, nervous conductivity and cellular metabolism and due to which blood volume, i.e. osmotic pressure and regulation in the human body is maintained (Armstrong, 2000). Owing to this physiological-thermal stress and central fatigue had increased even more.

The results obtained are in accord with those obtained by other researchers and they prove the fact that hyperthermia diminishes voluntary force and increases the degree of voluntary activation performing physical exercises that require endurance. The research done by L. Nybo and B. Nielsen (2001) has proved that during hyperthermia (rectal temperature ≈ 39.7ºC) MVC muscle force after 2 min of continuous load had decreased by 58% and the degree of voluntary activation — by 54%, compared to the control value. In the course of this study at the end of the load MVC muscle force had decreased by 60% and the degree of voluntary activation — by 86%, compared to the control value.

It may be supposed that the response of a physiological-thermic stress is conditioned by a number of factors with physiological mechanisms of liquid assimilation and the selection of methods of passive warming among them.

CONCLUSIONS

1. Applying the methods of passive muscle warming evoked hyperthermia and dehydration in the subjects, participants in the experiment.
2. During the experiments of hyperthermia and dehydration there occurred homogeneous changes in MVC fatigue.
3. Hyperthermia caused an increase in central fatigue.
4. Rehydration in conditions of hyperthermia increased central fatigue even more markedly.

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HIPERTERMIJOS IR DEHIDRATACIJOS POVEIKIS SUAUGUSIŲ MOTERŲ GRIAUČIŲ RAUMENŲ NUOVARGIUI ATLIEKANT MAKSIMALAUS INTENSYVUMO IZOMETRINIUS PRATIMUS

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SANTRAUKA

Tyrimo tikslas — nustatyti hipertermijos ir dehidratacijos poveikį maksimaliai valingajai jėgai (MVJ), centriniam nuovargiui ir įvertinti, kaip hipertermijos sąlygomis (atliekant 2 min maksimalų izometrinį krūvį) rehidratacija veikia griaučių raumenų funkcijas.

Tiriamosios — suaugusios aktyviai nesportuojančios moterys (n = 8). Jų amžius — 21,2 ± 2,4 metų, kūno svoris — 64,84 ± 8,4 kg, ūgis —170,8 ± 2,5 cm. Atlikti trys tyrimai — vienas kontrolinis, du eksperimentiniai. Vieno eksperimento metu buvo sukeliama organizmo hipertermija ir dehidratacija (tiriamosios 45 min sėdėjo iki dubens panirusios šiltoje vonioje, kurios vandens temperatūra 44 ± 1ºC), kito — ta pačia metodika sukeliant hipertermiją buvo atliekama peroralinė organizmo rehidratacija 1000 ml 37ºC NaCl 0,9% tirpalu. Maksimalus valingosios jėgos (MVJ) krūvis tęsėsi 120 s (kas 15 s raumuo buvo stimuliuojamas elektros impulsais — stimuliacijos trukmė 250 ms, dažnis 100 Hz, įtampos dydis 85—105 V). Registruotas raumenų MVJ momentas (N x m) ir raumenų valingojo aktyvavimo laipsnis: VA% = (MVJ + elektrinis impulsas) / MVJ × 100. Tiriamosios krūvio metu buvo žodžiu informuojamos, kaip kinta jėga.

Sukėlus hipertermiją ir dehidrataciją, rektalinė kūno temperatūra vidutiniškai padidėjo nuo 37,54 ± 0,24 iki 39,62 ± 0,25ºC (p < 0,001), raumenų vidinė temperatūra (3 cm gylyje) — nuo 36,97 ± 0,28 iki 39,96 ± 0,31ºC (p < 0,001). Atlikus rehidrataciją hipertermijos sąlygomis, rektalinė kūno temperatūra vidutiniškai padidėjo nuo 37,48 ± 0,25 iki 39,5 ± 0,23ºC (p < 0,001), raumenų — nuo 36,91 ± 0,29 iki 39,83 ± 0,31ºC (p < 0,001). Hipertermijos eksperimento metu tiriamosios vidutiniškai neteko 0,4 ± 0,07 kg, ir tai sudarė 0,62 ± 0,13% kūno svorio. Atlikus peroralinę rehidrataciją hipertermijos sąlygomis, tiriamųjų kūno svoris vidutiniškai padidėjo 0,48 ± 0,01 kg, ir tai sudarė 0,74 ± 0,08% bendrosios kūno masės. Išanalizavus fiziologinį šilumos streso indeksą (10 balų sistema) nustatyta, kad tiriamosios per abu eksperimentinius tyrimus patyrė labai didelį fiziologinį stresą: hipertermijos atveju — 8,85 ±1,13, rehidratacijos — 8,38 ± 0,98. Abiejų eksperimentinių tyrimų metu MVJ reikšmingai sumažėjo 3 krūvio sekundę, o per kontrolinį — 15 krūvio sekundę (p < 0,001), ir šis pokytis išliko iki MVJ-2 min pabaigos, lyginant su prieš krūvį nustatytais rodikliais. Atsigavimo metu, praėjus 5 min (A 300) po krūvio, MVJ rodikliai kontrolinio ir eksperimentinio hipertermijos tyrimo metu grįžo iki prieš krūvį nustatyto dydžio (p > 0,05). Dviejų veiksnių dispersinė analizė atskleidė, kad jėgos rodiklių pokytis priklausė nuo laiko (p < 0,001), būsenos (p = 0,021), o sąveikos tarp jų rezultato skirtumo reikšmingai nepaveikė (p > 0,05). Išanalizavus valingojo aktyvavimo rodiklius pastebėta, kad hipertermija (p < 0,05) ir rehidratacija (p < 0,01) reikšmingai padidino raumenų valingojo aktyvavimo laipsnį VA%, lyginant su prieš krūvį nustatytu. Atsigavimo metu, praėjus 15 s (A 15) po krūvio, valingojo aktyvavimo jėgos rodikliai grįžo iki prieš krūvį nustatyto dydžio. Atlikus dviejų veiksnių dispersinę analizę nustatyta, kad analizuojamų valingojo aktyvavimo jėgos rodiklių pokytis priklausė nuo laiko (p < 0,001), būsenos (p = 0,047) ir sąveikos tarp jų (p < 0,05).

Taikydami pasyvaus raumenų šildymo metodiką, tiriamųjų organizme sukėlėme hipertermiją ir dehidrataciją. Hipertermija padidino centrinį nuovargį. Hipertermijos ir rehidratacijos eksperimentų metu MVJ nuovargis kito vienodai. Rehidratacija hipertermijos sąlygomis turėjo neigiamos įtakos ir dar labiau padidino centrinį nuovargį atliekant 2 min maksimalų izometrinį krūvį.

Raktažodžiai: hipertermija, izometriniai pratimai, dehidratacija, rehidratacija, centrinis nuovargis.

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INTERRELATION BETWEEN EXERCISE HEART RATE, POST-RUN SYSTOLIC BLOOD PRESSURE, AND MYOCARDIAL STRUCTURE IN DISTANCE RUNNERS

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ABSTRACT

Endurance running is an exercise practiced by athletes in many sports. Being beneficial to health, it is also undertaken by a great number of non-athletic individuals. Rigorous endurance training frequently induces symmetric (i. e. both ventricular chamber dilation and wall thickening) myocardial hypertrophy, which is a physiological adaptation. Although distance running is a sport associated with haemodynamic volume rather than pressure overload, in addition to enlarged cardiac output, systolic arterial blood pressure also considerably increases during running. The extent of the cardiac hypertrophy was shown to be correlated with peak blood pressure measured during laboratory exercise. However, the predominant type of myocardial hypertrophy (the ratio between the myocardial wall thickness and chamber size) in endurance runners remains contradictory, and the majority of the responsible factors are still to be determined. The aim of this study was to determine possible correlations between post-run systolic blood pressure and myocardial hypertrophy in endurance runners.

Standard transthoracic two-dimensional M-mode echocardiography was performed in white adult male distance runners (n = 49) of national level within four weeks of treadmill testing, which was a non-continuous incremental exercise test employed for the determination of the heart rate as well as post-exertional systolic blood pressure response. Runners' training volume (evaluated as the average number of hours per week spent training averaged over the past four weeks) correlated ($p < 0.05$) positively with the left ventricular (LV) wall thickness but not with the cavity size or LV mass ($p > 0.05$). Training volume also positively correlated with systolic blood pressure response to exercise ($p < 0.05$), but negatively with submaximal exercise heart rate ($p < 0.01$). Post-run systolic blood pressure correlated positively with LV wall thickness and LV concentricity (namely, the ratio between the myocardial wall thickness and chamber size) ($p < 0.05$), but no significant correlation of any of the LV size parameters with resting heart rate, blood pressure, or systolic blood pressure in 2 to 4 min during the recovery period was revealed. Submaximal and maximal heart rate correlated significantly and negatively with LV wall thickness, LV mass, and systolic blood pressure measured immediately after running ($p < 0.05$).

Training volume and post-run systolic blood pressure have been found to correlate positively with LV wall thickness and concentricity in white adult male distance runners. Negative correlation of exercise heart rate has been found with the post-exercise systolic blood pressure, LV wall thickness, and LV mass.

Keywords: *myocardial hypertrophy, pressure overload, echocardiography, athlete's heart.*

INTRODUCTION

In contrast to the majority of other mammals, humans are naturally equipped for endurance running (Bramble, Lieberman, 2004). Distance running is a classical endurance exercise practiced by athletes of many sport disciplines. It is also undertaken by many non-athletic individuals and has a positive impact on health. Regular endurance training sufficient in volume and intensity triggers 'symmetric' (i. e. both ventricular chamber dilation and wall thickening) myocardial hypertrophy, which is considered a purely physiological adaptation (De Castro et al., 2006).

Distance running is classified as a sport associated with haemodynamic volume rather than pressure overload (Mitchell et al., 2005). However, in addition to both increased heart rate and systolic volume, systolic blood pressure (SBP) also considerably increases during running, and large fluctuations of pulse pressure are observed, and the extent of the cardiac hypertrophy was shown to correlate with peak blood pressure measured during laboratory exercise (Palatini et al., 1989). The arterial pulse pressure response to exercise was shown to be one of the determinants of concentricity (i. e. more pronounced wall thickening rather than chamber dilation (Haykowsky et al., 2002)) of runners' myocardium (Kasikcioglu et al., 2005). While competitive distance runners in response to their training are believed to develop symmetrical (i. e. both cardiac dilation and wall thickening of similar degree) or even eccentric (Pluim et al., 2000) (i. e. more pronounced chamber dilation rather than wall thickening (Haykowsky et al., 2002)) physiological cardiac hypertrophy, the concentric myocardial hypertrophy has been reported in professional endurance athletes who practice running as a sizeable component of their training and competition (Karjalainen et al., 1997; Palazzuoli et al., 2002; Venckunas et al., 2006). Anyway, the predominant type of myocardial hypertrophy in endurance runners remains clearly contradictory, as many authors have reported more pronounced chamber dilation as compared with wall thickening in these athletes (Morganroth et al., 1975; D'Andrea et al., 2002; Nagashima et al., 2003). There is even less understanding of the mechanisms involved in and the factors responsible for the development of the structural adaptation due to athletic conditioning (Kasikcioglu et al., 2005).

As one of the most potent stimuli for cardiac hypertrophy is arterial blood pressure, we have hypothesized that running-triggered haemodynamic pressure overload, measured as post-run SBP, explains (is responsible for) a significant proportion of LV wall thickness. The aim of the study was to determine possible correlations between post-run SBP and myocardial hypertrophy in endurance runners.

METHODS

Sample. The permission to conduct the study was given by the Regional Bioethics Committee. Forty-nine adult (18 to 42 years of age) male runners of national level who had been training for competitive distances from 800 m to the marathon were included in the study after their informed consent had been obtained. All the athletes were Caucasian and in their active training season at the time of the examination. They completed questionnaires to report their age, training experience in years, and weekly training volume in hours, averaged over the past four weeks. Athletes disclaimed usage of any chemical preparations. Clinical and training characteristics of the subjects are presented in Table 1.

Treadmill testing. A progressive incremental non-continuous exercise test was performed on a motorized treadmill (H/p/Cosmos Mercury 4.0, Nussdorf-Traunstein, Germany). The runners did not train at least 16 h and did not have meals at least 2 h before the testing. All the subjects were familiar with treadmill running.

The test consisted of 4-min running bouts of increasing intensity interspaced with 4-min passive rest spans in a seated position. The initial speed was 60% of the subject's average running velocity achieved during his last 5000-m race. Then the speed was increased by 0.7 km / h each bout. Subjects ran on the treadmill a sufficient number of times to increase the blood lactate concentration above the level of 4 mmol·L^{-1}. Blood samples from fingertips were analysed by an enzymatic membrane. After each running stage, the athletes dismounted from the treadmill and were seated immediately. Cuff SBP was measured within 20 s, and also at 2 and 4 min of the recovery period, always by the same investigator. Values of SBP measured immediately after cessation of running were carefully analysed. Maximal and minimal SBP values, as well as the SBP value after the last running stage were obtained for each athlete. In addition, all the SBP values

Age, years	Height, m	Body mass, kg	BMI, kg·m^{-2}	BSA, m^2	Systolic BP, mmHg	Diastolic BP, mmHg	Heart rate, beats·min^{-1}	Training experience, years	Training volume, hours / week
24.6 (7.4)	1.80 (0.06)	69.9 (5.9)	21.5 (1.8)	1.89 (0.09)	133.0 (13.3)	73.0 (10.2)	56.6 (9.7)	9.8 (7.3)	8.1 (3.3)

Table 1. **Subjects' clinical and training characteristics**

Note. BMI — body mass index; BSA — body surface area; BP — arterial blood pressure.

measured immediately after cessation of running were averaged for each subject. The difference between resting and exercise SBP was calculated by subtracting the averaged post-exercise SBP by resting SBP. As regards the later recovery period blood pressure, only the subject's average SBP at 2 and 4 min (separately) was analysed. Heart rate (HR) was recorded continuously averaging each 5-s interval (HR monitor Polar Accurex-Plus, Kempele, Finland). Maximal HR was determined as the highest 10-s interval value during the final stages of the treadmill test, and HR at the running speed of 15 km / h was extrapolated from the recorded exercise HR.

Echocardiography. Standard two-dimensional M-mode echocardiography, using ultrasound sonographer AU3 Partner (Esaote Biomedica, Genoa, Italy) with 2.5-MHz transducer, was performed within four weeks of treadmill testing, as described earlier (Venckunas et al., 2006). Internal LV diameter, interventricular septal (IVS) and LV posterior wall (PWT) thicknesses were measured at end-diastole as recommended by the American Society of Echocardiography. The same professional cardiologist took three measurements of each of the parameters, and the average was calculated. Left ventricular mass (in g) was calculated using the following equation:

$$LV_{mass}=0.8 \times \{1.04 \times ((IVS + LVED + PWT)^3 - (LVED)^3)\} + 0.6,$$

where IVS is interventricular septum thickness, PWT is left ventricular posterior wall thickness and LVEDd is left ventricular internal diameter (all at end-diastole, in cm).

Echocardiographic indices relative to body size were obtained by dividing absolute values by the body surface area (BSA) value of the same index order, i. e. LV wall thicknesses and diameter were divided by square rooted BSA, and LV mass was divided by square rooted and then cubed BSA. Body surface area was calculated according to the following formula (Du Bois, Du Bois, 1916): BSA (m^2) = $[\text{stature (cm)}]^{0.725} \times [\text{body mass (kg)}]^{0.425} \times 0.007184$.

The relative wall thickness (RWT) was calculated by dividing the sum of end-diastolic interventricular septum and LV posterior wall thicknesses by LV end-diastolic diameter. Resting cuff blood pressure (both systolic and diastolic) and heart rate were measured after the echocardiographic examination.

Statistics. The Pearson's bivariate two-tailed test was used in calculating the correlation coefficients. Echocardiographic LV size indices correlated with the following independent variables: SBP, HR, and training parameters. The significance level was set at *p* value of 0.05. All the analyses were performed with the SPSS for Windows release 13.0.

RESULTS

Runners' training volume correlated positively with absolute and relative IVS, PWT, as well as RWT (r from 0.283 to 0.368, $p < 0.05$), but not LV cavity size, LV mass or LV mass index ($p > 0.05$). Training volume also positi-

Table 2. **Correlation of left ventricular structure to systolic blood pressure (SBP) and heart rate (HR) response to treadmill running. Significant ($p < 0.05$) correlation coefficients are presented**

	IVS	IVSrel	PWT	PWTrel	RWT	LVM	LVMi
SBPaver	0.282 p = 0.049		0.306 p = 0.032	0.309 p = 0.031	0.319 p = 0.025		
SBP@15km / h			0.292 p = 0.047	0.292 p = 0.047	0.294 p = 0.045		
SBPmax				0.293 p = 0.043	0.348 p = 0.015		
SBPlast			0.334 p = 0.043	0.338 p = 0.041	0.344 p = 0.037		
SBPmin			0.301 p = 0.037	0.302 p = 0.037			
HRmax	–0.361 p = 0.014	–0.348 p = 0.018	–0.433 p = 0.003	–0.423 p = 0.003		–0.476 p = 0.001	–0.473 p = 0.001
HR@15km / h	–0.327 p = 0.022	–0.292 p = 0.042	–0.322 p = 0.024	–0.290 p = 0.043		–0.429 p = 0.002	–0.375 p = 0.008

Note. IVS — interventricular septum thickness; IVSrel — relative interventricular septum thickness; PWT — left ventricular posterior wall thickness; PWTrel — relative left ventricular posterior wall thickness; RWT — relative wall thickness; LVM — left ventricular mass; LVMi — left ventricular mass index; SBPaver — averaged systolic blood pressure immediately after running; SBP@15km/h — systolic blood pressure immediately after running at 15 km / h; SBPmax — maximal recorded systolic blood pressure immediately after running; SBPlast — systolic blood pressure immediately after the last running bout; SBPmin — the lowest recorded systolic blood pressure immediately after running; HRmax — maximal heart rate; HR@15km/h — heart rate immediately after running at 15 km / h.

vely correlated with SBP response to exercise (r from 0.41 to 0.48, $p < 0.01$), as well as SBPaver and HRmax product (r = 0.371, p = 0.011), but negatively with HR@15km / h (r = –0.422, p = 0.003).

Significant ($p < 0.05$) correlation coefficients of echocardiographic LV hypertrophy parameters to SBP and HR response to running are presented in Table 2.

Absolute LV diastolic diameter, but not wall thickness or LV mass, showed positive correlation with BSA (r = 0.544, p = 0.001), pulse pressure at rest (r = 0.339, p = 0.018), and negative correlation with the difference between resting and exercise SBP (–0.340, p = 0.017). The latter parameter also correlated with RWT (0.329, p = 0.021). Pulse pressure at rest also correlated with relative LV diameter (r = 0.331, p = 0.022) and LV mass (r = 0.309, p = 0.033). However, no significant correlation of any of the LV size parameters with resting HR or blood pressure, or SBP in 2 to 4 min during the recovery period was observed.

Both HRmax and HR@15km/h correlated negatively with the parameters of absolute and relative LV hypertrophy (Table 2), as well as SBP measured immediately after running ($r \approx -0.38$, all $p < 0.04$).

DISCUSSION

The study has revealed a positive correlation of post-run systolic blood pressure with LV wall thickness and concentricity in distance runners. This could be explained by the ability of athlete's heart with thicker myocardial wall to contract more powerfully during treadmill testing. An alternative interpretation is that more concentric myocardium hypertrophy is due to higher pressure response to daily training. These mechanisms may complement each other. The study has also shown that submaximal and maximal heart rate correlated negatively with LV wall thickness, LV mass, and systolic blood pressure measured immediately after running.

Some echocardiographic characteristics were shown to be influenced by the sport undertaken (Barbier et al., 2006). Increased myocardial mass due to both cavity dilation and wall thickening is a usual finding in endurance runners (Pluim et al., 2000; Fagard, 2003). Professional distance runners, though for a long time they were believed to possess more pronounced LV chamber dilation than wall thickening (Morganroth et al., 1975), were also shown not to have considerably lower relative wall thickness as compared with athletes from many other sports (Fagard, 2003; Hoogsteen et al., 2004), and even to be similar in LV cavity diameter to sedentary controls at least in one study (Palazzuoli et al., 2002).

Several physiological factors including endocrine, pressure responses to exercise, as well as diastolic filling pattern influence structural cardiac adaptation to regular exercise. Dynamic exercises including running favour venous return (Crawford et al., 1985; Goldhammer et al., 1999; Sundstedt et al., 2004), diastolic filling and accompanying distension of ventricular myocardium (mechanical stimulus to cardiac myocytes). Training volume and the duration of the haemodynamic overload as well as shifts in the hormonal milieu are also important factors which determine the extent of structural cardiac adaptation, namely myocardial mass. The results of the present study suggest that the amount of endurance running performed has an influence on distance runners' LV wall thickness rather than chamber size. Longer mechanical stimulus of voluminous training, instead of triggering dilation of the chamber, seems to induce net cardiac protein synthesis (wall thickening) and in such a way 'compensates' for the lower pressure overload during running as compared to the values triggered by strength / power athletes endeavour (MacDougall et al., 1985). This could plausibly explain the absence of lower (relative) myocardial wall thickness in long distance runners as compared with strength athletes (Fagard, 2003).

Interestingly, runners' training volume was not only negatively associated with submaximal heart rate, but also positively correlated with SBP increase due to exercise. The latter correlation might be explained by the ability of a better trained myocardium to contract more powerfully, and by the lower concentration of vasodilative metabolites produced, which leads to higher peripheral resistance at the same absolute workload in a better trained endurance runner.

Blood pressure during exercise is another possible factor involved in the development of both the type and the extent of cardiac hypertrophy (Karjalainen et al., 1997; D'Andrea et al., 2002). It remains controversial whether the extent to which SBP increase to exercise is or is not related to cardiovascular risk (Tanaka et al., 1996;

Campbell et al., 1999). In non-athletes, maximal exercise SBP correlated with SBP at rest (Bassett et al., 1998), which was not the case in our study of athletes.

In strength-trained athletes, peak laboratory cycling SBP correlated with LV wall thickness (D'Andrea et al., 2002). In ultra-endurance triathletes, LV mass correlated positively with blood pressure during 8-hour physical exercise (Douglas et al., 1986); in endurance athletes, with peak veloergometric blood pressure (Karjalainen et al., 1997); and in middle distance runners, with peak pulse pressure attained during laboratory treadmill testing (Kasikcioglu et al., 2005). As regards the latter observation, direct (invasive) measurements have revealed not only a marked elevation of the SBP during rowing (Clifford et al., 1994) and running (Palatini et al., 1989), but also large intra-arterial systolic and pulse pressure fluctuations not only during oar strokes in rowers (Clifford et al., 1994) but also due to foot strikes during running (Palatini et al., 1989): mean blood pressure changes little during running, both systolic and diastolic blood pressure fluctuate in synchrony, creating oscillations in radial artery pulse pressure of 20 to 200 mmHg (Palatini et al., 1989), and only slightly smaller oscillations have been recorded in the aorta during running (Rowell et al., 1968). This response, called 'beat phenomenon', is due to a foot-ground contact-generated pulse wave, which counters and sums up with the pulse wave created by the myocardial systole (Palatini et al., 1989). Foot strike also impacts the heart, additionally perturbing the consecutive myocardial contractions (Palatini et al., 1989; Derrick et al., 1998). However, as it cannot be denied that pulse pressure during running (also) fluctuates due to pressure waves in the tissues around the blood vessels, it is possible that arterial pressure oscillations do not reflect the arterial transmural pressure (Palatini et al., 1989). In any case, during running the heart has to pump blood in the presence of increased both preload and afterload (Rowel et al., 1968; Palatini et al., 1989).

The implications of beat phenomenon are not clear, though they may be related to the redistribution of blood flow (Palatini et al., 1989). Pulse pressure during running, though related to running technique, is not a good proxy of stroke volume (Palatini et al., 1989). Foot strikes become stronger during fatigue (Hamill et al., 1995), and then 'beats' would emerge more clearly. It was proposed that such large fluctuations could provide additional stimulus for cardiac hypertrophy (Clifford et al., 1994). However, we did not monitor blood pressure during actual running, and beats disappear on the discontinuation of running, when blood pressure was actually measured in our study.

CONCLUSIONS

Runners' training volume and systolic blood pressure in response to treadmill running have been disclosed to correlate positively with myocardial wall thickness and concentricity of left ventricular hypertrophy in white young adult male distance runners. Both maximal and submaximal exercise heart rate has been found to correlate negatively with post-exercise systolic blood pressure, left ventricular wall thickness, and left ventricular mass.

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BĖGIKŲ SISTOLINIO ARTERINIO KRAUJOSPŪDŽIO PO KRŪVIO, ŠIRDIES SUSITRAUKIMŲ DAŽNIO KRŪVIO METU IR MIOKARDO STRUKTŪROS TARPUSAVIO SĄSAJA

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SANTRAUKA

Ištvermės lavinamasis bėgimas taikomas rengiant daugelio sporto šakų atletus. Jis yra viena iš svarbiausių bendrosios populiacijos sveikatinimo priemonių. Intensyvios ir reguliarios ištvermės lavinamojo bėgimo pratybos dažnai sukelia simetrišką fiziologinio pobūdžio miokardo hipertrofiją, t. y. širdies skilvelio sienelės sustorėjimą kartu su jo ertmės padidėjimu. Nors ilgųjų nuotolių bėgimas daugiausia siejamas su padidėjusia širdies ir kraujagyslių sistemos apkrova, ištvermės lavinamojo bėgimo metu be padidėjusio minutinio širdies tūrio smarkiai išauga sistolinis arterinis kraujospūdis. Miokardo hipertrofijos dydis koreliuoja su didžiausiu laboratorinio testo metu pasiekiamu kraujospūdžiu, tačiau ilgųjų nuotolių bėgikų miokardo hipertrofijos tyrimų rezultatai skiriasi. Lieka neaišku, nuo ko tai daugiausia priklauso. Tyrimo tikslas — nustatyti galimą ryšį tarp sistolinio arterinio kraujospūdžio, išmatuoto po bėgimo testo, ir bėgikų miokardo hipertrofijos dydžio.

Standartinė transtorakalinė echokardiografija atlikta ištvermę lavinantiems (vidutinių ir ilgųjų nuotolių) bėgikams (n = 49) likus ne daugiau kaip mėnesiui iki testavimo laboratorijoje bėgtakiu — intervalinio nuolat sunkinamo testo metu buvo išmatuotas širdies susitraukimų dažnis bėgant ir sistolinis kraujospūdis po bėgimo.

Bėgikų treniravimosi apimtis (vidutiniškai valandomis per savaitę) koreliavo ($p < 0,05$) su kairiojo širdies skilvelio (KS) sienos storio rodikliais, tačiau nebuvo susijusi su KS vidiniu skersmeniu ar mase ($p > 0,05$). Treniravimosi apimtis taip pat teigiamai koreliavo su sistolinio kraujospūdžio reakcija į bėgimo krūvį, tačiau neigiamai — su submaksimaliu širdies susitraukimų dažniu bėgimo testo metu ($p < 0,01$). Po bėgimo išmatuotas sistolinis kraujospūdis tiesiogiai koreliavo su KS sienos storio rodikliais ir KS koncentriškumu ($p > 0,05$), tačiau reikšmingos koreliacijos tarp KS struktūros dydžių ir ramybės širdies susitraukimų dažnio, ramybės kraujospūdžio ar sistolinio kraujospūdžio antrą—ketvirtą atsigavimo minutę nebuvo. Bėgimo metu pasiekto submaksimalaus ir maksimalaus širdies susitraukimų dažnio rodikliai neigiamai koreliavo su KS sienos storio duomenimis, KS mase ir sistoliniu kraujospūdžiu, išmatuotu tuoj pat po bėgimo ($p < 0,05$).

Taigi treniravimosi apimtis ir sistolinis kraujospūdis po bėgimo teigiamai koreliuoja su jaunų bėgikų kairiojo širdies skilvelio koncentriškumo ir sienos storio rodikliais. Tarp širdies susitraukimų dažnio bėgimo metu ir sistolinio kraujospūdžio bei kairiojo širdies skilvelio masės ir sienos storio rodiklių nustatyta neigiama koreliacija.

Raktažodžiai: miokardo hipertrofija, perkrova slėgiu, echokardiografija, sportininko širdis.

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1.6. Du rankraščio egzemplioriai ir diskelis siunčiami žurnalo „Ugdymas. Kūno kultūra. Sportas“ redaktorių kolegijos atsakingajai sekretorei šiuo adresu:

Žurnalo „Ugdymas. Kūno kultūra. Sportas“ atsakingajai sekretorei Daliai Mickevičienei
Lietuvos kūno kultūros akademija, Sporto g. 6, LT-44221 Kaunas

1.7. Žinios apie visus straipsnio autorius — trumpas curriculum vitae. Autoriaus adresas, elektroninis adresas, faksas, telefonas.

1.8. Gaunami straipsniai registruojami. Straipsnio gavimo paštu data nustatoma pagal Kauno pašto žymeklį.

2. STRAIPSNIO STRUKTŪROS REIKALAVIMAI

2.1. **Titulinis lapas**.

2.2. **Santrauka** (ne mažiau kaip 2000 spaudos ženklų, t. y. visas puslapis) lietuvių ir anglų kalba. Santraukose svarbu atskleisti mokslinę problemą, jos aktualumą, tyrimo tikslus, uždavinius, metodus, pateikti pagrindinius tyrimo duomenis, jų aptarimą (lyginant su kitų autorių tyrimų duomenimis), išvadas.

2.3. **Raktažodžiai.** 3—5 informatyvūs žodžiai ar frazės.

2.4. **Įvadinė dalis.** Joje nurodoma tyrimo problema, jos ištirtumo laipsnis, sprendimo naujumo argumentacija (teorinių darbų), pažymimi svarbiausi tos srities mokslo darbai, tyrimo tikslas, objektas.

2.5. **Tyrimo metodai.** Šioje dalyje turi būti pagrįstas konkrečios metodikos pasirinkimas. Jei taikomi tyrimo metodai nėra labai paplitę ar pripažinti, reikia nurodyti priežastis, skatinusias juos pasirinkti. Aprašomi originalūs metodai arba pateikiamos nuorodos į literatūroje aprašytus standartinius metodus, nurodoma aparatūra (jei ji naudojama). Tyrimo metodai ir organizavimas turi būti aiškiai ir logiškai išdėstyti.

Straipsnyje neturi būti informacijos, pažeidžiančios tiriamų asmenų anonimiškumą.

2.6. **Tyrimo rezultatai.** Tyrimo rezultatai turi būti pateikiami nuosekliai ir logiškai (pageidautina pateikti ne daugiau kaip 3—4 lenteles ar 4—5 paveikslus), pažymimas jų statistinis patikimumas.

2.7. **Tyrimo rezultatų aptarimas.** Šioje dalyje pateikiamos tik autoriaus tyrimų rezultatais paremtos išvados. Tyrimo rezultatai ir išvados lyginami su kitų autorių skelbtais atradimais, įvertinami jų tapatumai ir skirtumai. Reikia vengti kartoti tuos faktus, kurie pateikti tyrimų rezultatų dalyje. Išvados turi būti formuluojamos aiškiai ir logiškai, vengiant tuščiažodžiavimo.

2.8. **Padėka.** Dėkojama asmenims arba institucijoms, padėjusiems atlikti tyrimus. Nurodomos organizacijos ar fondai, finansavę tyrimus (jei tokie buvo).

2.9. **Literatūra.** Cituojami tik publikuoti mokslo straipsniai (išimtis — apgintų disertacijų rankraščiai). Į sąrašą įtraukiami tik tie šaltiniai, į kuriuos yra nuorodos straipsnio tekste. Pageidautina nurodyti ne daugiau kaip 30 šaltinių.

3. STRAIPSNIO ĮFORMINIMO REIKALAVIMAI

3.1. Straipsnio tekstas turi būti išspausdintas kompiuteriu vienoje standartinio (210 × 297 mm) formato balto popieriaus lapo pusėje, intervalas tarp eilučių 6 mm (1,5 intervalo), šrifto dydis 12 pt. Paraštės: kairėje ir dešinėje — 2 cm, viršuje — 2 cm, apačioje — 1,5 cm. Puslapiai numeruojami viršutiniame dešiniajame krašte, pradedant tituliniu puslapiu, kuris pažymimas pirmu numeriu (1).

3.2. **Straipsnis turi būti suredaguotas, spausdintas tekstas patikrintas.** Pageidautina, kad autoriai vartotų tik standartinius sutrumpinimus bei simbolius. Nestandartinius galima vartoti tik pateikus jų apibrėžimus toje straipsnio vietoje, kur jie įrašyti pirmą kartą. Visi matavimų rezultatai pateikiami tarptautinės SI vienetų sistemos dydžiais. Straipsnio tekste visi skaičiai iki dešimt imtinai rašomi žodžiais, didesni — arabiškais skaitmenimis.

3.3. Tituliniame straipsnio puslapyje pateikiama: a) trumpas ir informatyvus straipsnio pavadinimas; b) autorių vardai ir pavardės; c) institucijos bei jos padalinio, kuriame atliktas darbas, pavadinimas ir adresas; d) autoriaus, atsakingo už korespondenciją, susijusią su pateiktu straipsniu, vardas, pavardė, adresas, telefono (fakso) numeris, elektroninio pašto numeris. Jei autorius nori turėti slaptos recenzijos teisę, pridedamas antras titulinis lapas, kuriame nurodomas tik straipsnio pavadinimas.

Tituliniame lape turi būti visų straipsnio autorių parašai.

3.4. Santraukos lietuvių ir anglų (rusų) kalbomis pateikiamos atskiruose lapuose. Tame pačiame lape surašomi raktažodžiai.

3.5. Lentelė turi turėti eilės numerį (numeruojama ta tvarka, kuria pateikiamos nuorodos tekste) bei trumpą antraštę. Visi paaiškinimai turi būti straipsnio tekste arba trumpame prieraše, išspausdintame po lentele. Lentelėse vartojami simboliai ir sutrumpinimai turi sutapti su vartojamais tekste. Lentelės vieta tekste turi būti nurodyta kairėje paraštėje (pieštuku).

3.6. Paveikslai sužymimi eilės tvarka arabiškais skaitmenimis. Pavadinimas rašomas po paveikslu, pirmiausia pažymint paveikslo eilės numerį, pvz.: 1 pav. Paveikslo vieta tekste turi būti nurodyta kairėje paraštėje (pieštuku).

3.7. Literatūros sąraše šaltiniai nenumeruojami ir vardijami abėcėlės tvarka pagal pirmojo autoriaus pavardę. Pirma vardijami šaltiniai lotyniškais rašmenimis, paskui — rusiškais.

Pateikiant žurnalo (mokslo darbų) straipsnį, turi būti nurodoma: a) autorių pavardės ir vardų inicialai (po pavardės); b) žurnalo išleidimo metai; c) tikslus straipsnio pavadinimas; d) pilnas žurnalo pavadinimas; e) žurnalo tomas, numeris; f) atitinkami puslapių numeriai. Jeigu straipsnio autorių daugiau kaip penki, pateikiamos tik pirmų trijų pavardės priduriant „ir kt.“.

Aprašant knygą, taip pat pateikiamas knygos skyriaus pavadinimas ir jo autorius, knygos leidėjas (institucija, miestas).

Jeigu to paties autoriaus, tų pačių metų šaltiniai yra keli, būtina literatūros sąraše ir straipsnio tekste prie metų pažymėti raides, pvz.: 1990 a, 1990 b ir t. t.

Literatūros aprašo pavyzdžiai:

Gikys, V. (1982). *Vadovas ir kolektyvas*. Vilnius: Žinija.

Jucevičienė, P. (Red.) (1996). *Lyginamoji edukologija*. Kaunas: Technologija.

Miškinis, K. (1998). *Trenerio etika: vadovėlis Lietuvos aukštųjų mokyklų studentams*. Kaunas: Šviesa.

Ostasevičienė, V. (1998). Ugdymo teorijų istorinė raida. A. Dumčienė ir kt. (Red. kol.), *Ugdymo teorijų raidos bruožai: teminis straipsnių rinkinys* (pp. 100—113). Kaunas: LKKI.

Šveikauskas, Z. (1995). Šuolių technikos pagrindai. J. Armonavičius, A. Buliuolis, V. Butkus ir kt., *Lengvoji atletika: vadovėlis Lietuvos aukštųjų m-klų studentams* (pp. 65—70). Kaunas: Egalda.

Večkienė, N., Žalienė, I., Žalys, L. (1998). Ekonominis švietimas — asmenybės ugdymo veiksnys. *Asmenybės ugdymo edukologinės ir psichologinės problemos: respublikinės moksl. konferencijos medžiaga* (pp. 159—163). Kaunas: LKKI.

Vitkienė, I. (1998). Kai kurių mikroelementų pokyčiai lengvaatlečių kraujyje fizinio krūvio metu. *Sporto mokslas,* 1 (10), 12—13.

INFORMATION TO AUTHORS

1. GENERAL INFORMATION

1.1. All papers submitted to the journal should contain original research not previously published (except abstracts, preliminary report or in a thesis). The material published in the journal should be new, true to fact and precise. The methods and procedures of the experiment should be identified in sufficient detail to allow other investigators to reproduce the results. It is desirable that the material to be published should have been discussed previously at conferences or seminars.

1.2. Original articles — manuscripts up to 10 printed pages, review articles — manuscripts up to 20 printed pages.

Review articles describe current topics of importance, primarily, though not always they are submitted by invitation. Individuals who wish to write a review article should correspond with the Editors regarding the appropriateness of the proposed topic and submit a synopsis of their proposed review before undertaking preparation of the manuscript.

1.3. Articles will be published in the Lithuanian or English languages with comprehensive resumes in English and Lithuanian.

1.4. All papers, including invited articles, undergo the regular review process by at least two members of the Editorial Board or by expert reviewers selected by the Editorial Board.

1.5. The author (reviewer) has the option of the blind review. In this case the author should indicate this in his letter of submission to the Editor-in-Chief. This letter is sent along with the article (review).

1.6. Two copies of the manuscript and floppy disk should be submitted to the Executive Secretary of the journal to the following address:

Dalia Mickevičienė, Executive Secretary of the journal "Education. Physical Training. Sport"
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221, Kaunas, LITHUANIA

1.7. Data about all the authors of the article — short Curriculum Vitae. The adress, e-mail, fax and phone of the author.

1.8. All papers received are registered. The date of receipt by post is established according to the postmark of the Kaunas post-office.

2. REQUIREMENTS SET FOR THE STRUCTURE OF THE ARTICLE

2.1. **The title page.**

2.2. **The abstract** (not less than 2000 print marks, i.e. the complete page) in English or (and) Lithuanian. It is important to reveal the scientific problem, its topicality, the aims of the research, its objectives, methods, to provide major data of the research, its discussion (in comparison with the research data of other authors) and conclusions.

2.3. **Keywords:** from 3 to 5 informative words and / or phrases which do not repeat themselves in the title of the article.

2.4. **The introductory part**. It should contain a clear statement of the problem of the investigation, the extent of its solution, the new arguments for its solution (for theoretical papers), most important papers on the subject, the purpose of the study and the object of the study.

2.5. **The methods of the investigation.** In this part the methods of the investigation should be stated. If the methods of the investigation used are not well known and widely recognised the reasons for the choice of a particular method should be stated. References should be given for all non-standard methods used. The methods, apparatus and procedure should be identified in sufficient detail.

Appropriate statistical analysis should be performed based upon the experimental design carried out.

Do not include information that will identify human subjects.

2.6. **Results of the study.** Findings of the study should be presented logically in the text, tables (not exceeding 3 or 4), or figures (not exceeding 4 or 5). The statistical significance of the findings when appropriate should be denoted.

2.7. **Discussion of the results of the study.** The discussion section should emphasise the original and important features of the study, and should avoid repeating all the data presented within the results section. Incorporate within the discussion the significance of the findings, and relationship(s) and relevance to published observations. Authors should provide conclusions that are supported by their data. The conclusions provided should be formulated clearly and logically avoiding excessive verbiage.

2.8. **Acknowledgements.** Authors are required to state on the Acknowledgement Page all funding sources, and the names of companies, manufacturers, or outside organizations providing technical or equipment support (in the case such a support had been provided).

2.9. **References.** Only published material (with the exception of dissertations) and sources referred to in the text of the article should be included in the list of references. As a general rule, there should not be more than 30 references for original investigations.

3. REQUIREMENTS FOR THE PREPARATION OF MANUSCRIPTS

3.1. Manuscripts must be typed on white standard paper no larger than 210 × 297 mm with the interval between lines 6 mm (1,5 line spaced), with a character size at 12 points, with 2 cm margins on the left and on the right, with a 2 cm margin at the top and a 1,5 cm margin at the bottom of the page. Pages are numbered in the upper right-hand corner beginning with the title page numbered as page 1.

3.2. The manuscript should be brief, clear and grammatically correct. The typed text should be carefully checked for errors. It is recommended that only standard abbreviation and symbols be used. All abbreviations should be explained in parentheses after the full written-out version of what they stand for on their first occurrence in the text. Non-standard special abbreviations and symbols need only to be defined at first mention. The results of all measuring and symbols for all physical units should be those of the System International (S.I) Units. In the text of the article all numbers up to ten are to be written in words and all numbers starting from eleven on — in Arabic figures. Be sure that all references and all tables and figures are cited within the text.

3.3. The title page should contain: a) a short and informative title of the article; b) the first names and family names of the authors; c) the name and the address of the institution and the department where the work has been done; d) the name, address, phone and fax number, E-mail number, etc. of the author to whom correspondence should be sent. If a blind review is requested a second title page that contains only the title is needed. The title page should be signed by all authors of the article.

3.4. Resumes in the Lithuanian and English languages are supplied on separate sheets of paper. This sheet also should contain keywords.

3.5. Every table should have a short subtitle with a sequential number given above the table (the tables are numbered in the same sequence as that of references given in the text). All explanations should be in the text of the article or in a short footnote added to the table. The symbols and abbreviations given in the tables should coincide with the ones used in the text. The location of the table should be indicated in the left-hand margin.

3.6. All figures are to be numbered consecutively giving the sequential number in Arabic numerals, e.g., Figure 1. The location of the figure should be indicated in the left-hand margin of the manuscript.

3.7. References should be listed in alphabetical order taking account of the first author.

For journal articles the following information should be included: a) author names (surnames followed by initials), b) the date of publication, c) the title of the article with the same spellings and accent marks as in the original, d) the journal title, e) the volume number, f) inclusive page numbers. When five or more authors are named, list only the first three adding "et al."

In the case when there are several references of the same author published at the same year, they must be marked by letters, e. g. 1990 a, 1990 b, etc. in the list of references and in the article, too.

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Examples of the correct format are as follows:

Bergman, P. G. (1993). Relativity. In *The New Encyclopedia Britannica* (Vol. 26, pp. 501—508). Chicago: Encyclopedia Britannica.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of Memory & Consciousness* (pp. 309—330). Hillsdale, N J: Erlbaum.

Deci, E. L., Ryan, R. M. (1991). A motivational approach to self: Integration in personality. In R. Dientsbier (Ed.), *Nebrasha Symposium on Motivation: Vol. 38. Perspectives on Motivation* (pp. 237—228). Lincoln: University of Nebraska Press.

Gibbs, J. T., Huang, L. N. (Eds.). (1991). *Children of Color: Psychological Interventions With Minority Youth.* San Francisco: Jossey—Bass.

Ratkevičius, A., Skurvydas, A., Lexell, J. (1995). Submaximal-excersise-induced impairment of human muscle to develop and maintain force at low frequencies of electrical stimulation. *European Journal of Applied Physiology,* 70, 294—300.

Town, G. P. (1985). *Science of Triathlon Ttraining an Competition.* Champaign, Illinois: Human Kinetics.