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SPORT, OLYMPISM AND TWO LIFESTYLES

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ABSTRACT

Research background and hypothesis. The study analyses two lifestyles: asceticism and hedonism. Spiritual and moral dimension of our lives form a wider background and the field of sport, especially renewed olympism, affect the closer one of our reflections.

Research aims were to compare both lifestyles and to make the character of their relation clear; to map the real role of asceticism in the sports sphere and to integrate both lifestyles into a certain meaningful whole.

Research methods. Our methodology is philosophical, involving conceptual analysis and the application of the outcomes to sports practice.

Research results. Both concepts have usually been considered as contrary or polar. Yet our analysis leads into persuasion that they are in dialectic relation with many mediations and "bridges" between them. Spiritual and moral dimensions play an important role in the topical reflections.

Discussion and conclusions. Many authors warn about the close junction between sports and asceticism. The role of hedonism is analyzed much less. We tried to find some balanced position within the framework of the integrated whole. The final part of the study tries to show that the topic ought to be joined with a horizon of meanings. Promoting "reasonable asceticism" can be one aspect of raison d´être of today's sport in this postmodern world with the supremacy of hedonistic orientation.

Keywords: asceticism, Pierre de Coubertin's attitudes, hedonism, meaning of life.

INTRODUCTION

Is the ethos or "philosophy" of modern sport ascetic? Why was the motto of the new Olympic movement – "Citius, altius, fortius" – regarded as an *antiascetic* one by P. de Coubertin[1]? The emergence of a sport during the 19th century with its target on the improvement of *bodily* skills and fitness (in the first plan) was a new phenomenon. Such target had its own reasons. Some of them are as follows:

The reemergence of the concept of *kalokagathia*. For example, Miroslav Tyrš in the Czech Republic began to renew and promote it in about 1850. He felt that the new life of that old Greek ideal needed much more attention to the problem of the human body (combined with beauty). We are sure he was not the only thinker of this kind in Europe in those days.

The deterioration of the level of physical skills and fitness. In the second half of the 19th century a new class of so called "contented young gentlemen" arose (not speaking about renters in general). Jose Ortega y Gasset was the author of the term and said that they were people taking surplus of means from the world, not sharing its anxiety (Gasset, 1930). Their style of life called for both compensation of the absence of physical effort and for entertainment. Sport could satisfy both.

Maybe a new "opium of mankind" was needed? It required a body! Ready and trained body! P. de Coubertin even spoke about a new *religio*

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[1] See his talk "Olympia" in Paris, March 6, 1929 (Müller, 2000, p. 569).

athletae – and the body was certainly not the only "ingredient" of it[2].

Anyway, a new "fraternity of the body and the mind" started. And where did the struggle between them run? In which type of ideology did concentration on soul and spirit and rejection of the body prevail? The answer is clear: in *christian* doctrine. *Asceticism* (its special sort) became a dominant feature in it. Now, from this point of view, we can better understand P. de Coubertin's antiascetic "label" for renewed olympism.

Yet, as the *sphere of asceticism* is considered, we must study more what asceticism really is and what its contexts and background are.

ASCETICISM

From the historical point of view, the Greek word *askesis* means "exercise". The first features of asceticism can be found in the Orphics (B. Russell speaks about "an ascetic sect" – see 1979, p. 39), and through the "proud asceticism" of Heraclitus we can continue to Socrates, Cynics etc. The comparison of the above mentioned Stoic, Christian and East (not speaking about the others) approaches to asceticism would exceed the range of our article, so we can only summarize the whole history.

We can find two main attitudes: a) saying NO to lower values and rejecting damaging influences or things, and b) saying YES to higher values and positive "building" of the appropriate virtues and skills. Of course, with the necessary portion of *askesis* in both relations.

We can apply it to modern sport in two aspects:

1. Attitude to the body: a) rejecting inappropriate food; sexual abstention; fight against other "temptations of the body", and b) active training towards physical perfection (corpus lacertosus[3]!) or real body building; the best alimentation and health care; "opening the body" for a flow of (A) energy without barriers and (B) optimal or other experiences. The latter effort is not possible without "cooperation" with the higher elements of our being (see below). We speak about the bodily anchored experiences, and sport is a very proper field for it, especially in comparison

with some therapeutic methods where "anchoring" must be arranged artificially (such as a technique for focusing (Gendlin, 1978)).

2. Attitude to psychical, moral and social factors: a) the struggle against different sorts of entertainment and lack of concentration ("temptation of mind"); reduction of external negative influences and impressions (to gain full independence and self-control). The great teachers here are the Stoics with their *ataraxia* (a balanced state of mind). The training of cultivation/ sublimation of all negative emotions and passions with the focus on sports achievements ought to be mentioned here as well. Let us remember the Stoics again with their *apatheia* (circa an internal state of quiet – the result of our struggle with weaknesses). Please do not confuse it with modern apathy – it is usually the result of our passiveness; and b) positive relation with higher values in these areas of human being is a sphere for so called *internal askesis*. It includes special training of concentration, memory, will, imagination etc.; focusing on moral and social values. Permanent and systematic (sports) work with ascetic rationalization of the whole lifestyle can be also mentioned here.

It is evident that the doors for the *spiritual* dimension of our topic are open here. "Per aspera ad astra"! We can speak about the techniques of meditation, but especially about a new area of very special experiences (optimal, flow, limit, deep, plateau, peak[4]) which are able to open new dimensions of our lives.

Today many sports teams or training groups are not far from monkhood. Sexual abstention or special diet before important competition, full subordination to trainer or other leader – we can see an analogy with the orientation on the virtues of abstention and obedience to religious orders. R. S. Kretchmar, a well-known philosopher of sport, warns about this connection in his chef d´oeuvre (2005) and uses the name "spiritual athletes" even for monks (living according the rule of St. Benedict) (!), as they "well understood the connection between physicality and spirituality, austerity and tranquility" (Kretchmar, 2005, p. 250). Ralph Barton Perry compared the lives of modern Olympic athletes to the Puritan "moral athletes" (Perry, 1944, p. 255–256).

The group of female runners of the despotic Chinese trainer Ma Junren is maybe the most

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[2] The other were „public-spiritedness, thoughts and art" (1918). See (Müller, 2000, p. 44).

[3] P de Coubertin´s Latin term from an attempt to create a new olympic motto in 1911: "Mens fervida in corpore lacertoso" (An ardent mind in a trained body). See (Müller, 2000, p. 175; 213).

[4] Studies by A. Maslow (1971; 1994 etc.) and M. Csikszentmihalyi (1990 etc.) are also full of inspiration for the sports.

known case of strict asceticism in the field of sport. We can find many cases of ascetic commitment among athletes of the four professional leagues in North America (baseball, basketball, football, ice hockey) as well: "… dedicated athletes deny themselves sex, alcohol, tobacco, food, sleep, physical comfort, and other pleasures." (Overman, 2011, p. 171)

Some results, especially in elite sport, look as if they are achieved without special ("ascetic") effort. We speak about situations from so called "zone". It is a special state of euphoria or easiness. It was described by J. Douillard (1994) in the field of sport and can be ranked among peak experiences[5]. Yet we are persuaded that state is not attainable without a previous period of "ascetic" training – it is hardly unattainable for "common" people.

HEDONISM

It is obvious that pure asceticism is not real in our lives. Can we imagine permanent fasting? And what about a permanent eating? We are sure that pure *hedonism* is also not real. The Greek word *hedone* means "pleasure" and is linked to a doctrine of Epicurus. We can find very different approaches concerning pleasures in the course of history: from the primitive pursuit of bodily lust to considering the highest pleasure in finding personal, scientific or religious truth, or as crowning creative acts with success; from Aristippus, who said: "Act to maximize pleasure now and do not worry about the future," to John Stuart Mill with his qualitative hedonism. And again, we can only summarize the history trying to find quintessence in it.

We can collate the "strategy" of asceticism with a similar one of hedonism in two main attitudes: a) saying YES to the chosen types of pleasures blissful feelings, delight or enjoyments, and b) saying NO to all types of pain, displeasure, distress, discomfort or difficulties. Some extremes, like ecstasy, lie out of classical hedonism and were condemned already by Epicurus. Here we can find ourselves at the same point rejecting lower values by asceticism. There is no coincidence that both Epicurus and the Stoics were using the same term *ataraxia* (see above).

Is there any place for *hedone* in the sports area? One type from B. Crum's classification of sportive sub-systems (1992) is directed straight to

hedonism with its focus on "exclusive pleasure". It is *lust sport*, special form of so called S-sport (sun, sea, sand, snow, sex, speed and satisfaction). The author warned about the risk of seeking fun and satisfaction at the cost of others in lust sport. We mean that it is a general problem of hedonistic orientations of life: they are egocentric, if not directly egoistic.

Can we find *hedone* in other sorts of sports sub-systems also? What about elite sport? It is obvious that qualifying for this category is not possible without outdoing oneself and without overcoming pain or stress (attributes of asceticism). But even top training has its own parts of strain and relaxation. The life of elite athletes has also its own periods of maximum training before some important competitions and periods of "post festum" with a celebration (quite popular after some successful performance): etc. Periods of asceticism and periods of hedonism are longer periods of the former and a shorter periods of the latter. Some portion of hedonism can be taken as a reward. We can also consider a hedonistic aim achieved through ascetic means. "Ad astra" (only) "per aspera". The concept of "long-run hedonist" (Edwards, 1979, p. 24) can be interesting in our context. It can be characterized by this motto: "Act to maximize pleasure over the entire span of your life." A calculation leading to the predominance of pleasure over pain is necessary in this form of hedonism; not saying that pain is not part of our lives. How can we argue against proper and acceptable pleasures leading to further enjoyment?

AN INTEGRATED WHOLE

Let us try to integrate both aspects of (not only sportive) life into a wider framework of the whole of human life. The best types of "strategies of life" from our point of view were given us by Aristotle (2009, 1095 b, P. 15–19):

1. *Bios apolaustikos* – orientation on pleasures and self-indulgence is the leading motivation.

2. *Bios politikos* – orientation on active life (especially political, ethical and practical) is the leading motivation.

3. *Bios theoretikos* – especially philosophical contemplation is the leading element here.

The second type (also known as *vita activa* in the Latin language) is of great value to Aristotle, but the most valuable is the third one (also known as *vita contemplativa* in the Latin language) – he spoke about "divine lifestyle".

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[5] For the close relation between peak, flow and zone experiences see M. Bednář, 2011.

According to Aristotle each type has its own representation among people. We can also imagine the development (or struggle) of all these types in one person. *Bios apolaustikos* in youth, *bios politikos* in the middle period of life and *bios theoretikos* in the period of growing wise (if it will come…).

Athletes are most familiar with *vita activa*, aren't they? But why could they not share a little more *vita contemplativa* as well? We think it is a great task for the philosophy of sport to show them this dimension of life and to teach them how to join it with other dimensions in *one organic whole*. Golfers have their hole-in-one; we can speak about "whole-in-one"… If we can speak about the "sportification of the society", why not take the highest form of social life and speak about the "spiritualization of sport", or better of sports life as a whole? Achieving this high aim should be predicated by the right criterion of happiness or bliss (*eudaimoniá*) in the meaning of life. There is a task to anchor sports activities not only for the sake of the body but also for the wider aim or meaning of life. A horizon of bliss should be surrounded with a horizon of meaning. Hedonism and asceticism are seen only as *means* from the point of the latter horizon. Here we can use the results of research (and personal experiences) of well-known V. E. Frankl and his *logotherapy*[6]. Let the analysis of it and possible application in the field of sport be the topic for a further research.

CONCLUSION AND PERSPECTIVES

Observing relevant literature from R. B. Perry (1944) to S. J. Overman (2011), we can see the dominating line of junction between sports and asceticism. An opposite attitude – the junction between sports and hedonism – is seen among the critics of postmodern life and some observers of the contemporary sports area. It is the egoism, hedonism, and mercenary inclinations of sports figures that appear most salient. Yet we agree with Overman: "Athletes as a group receive a great deal of notoriety in the popular media for their personal indulgences. But the very fact that famous athletes are held to a higher standard of behavior than other young adults speaks to the abiding moralism in contemporary ⟨…⟩ society." (Overman, 2011, p. 174) Sexual affairs of "exemplary and model" Tiger Woods are a perfect example both of split personality and pressure on the best athletes. But can we speak of hedonistic life orientation or lifestyle in this and similar cases? We do not think so. The better explanatory principle can be taken from Jung's teaching of archetypes, and especially the Shadow in our case. The more perfect we are, the bigger shadow arises in our unconsciousness – and the situation is ready for a conflict.

We could see that pure types of ascetics or hedonists are not possible to find both in a common or sports lives. We are a very special "mixture" of both types and *their relation is dialectic*, not polar. Yet one type is usually a leading one – we can expect stronger orientation on asceticism in the case of athletes. It is a task both for sports theory and practice to promote this orientation. To promote "reasonable asceticism" – without all extremes, of course. It can be also one aspect of raison d´être of today sport in this postmodern world with the supremacy of hedonistic orientation.

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[6] *Logos* is used here as "meaning/sense". See e. g. V. Frankl (1964).

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SPORTAS, OLIMPIZMAS IR DU GYVENIMO BŪDAI

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tyrimo metu analizuojami du gyvenimo būdai: asketizmas ir hedonizmas. Dvasinės ir moralinės gyvensenos dimensijos kuria mūsų gyvenimo ir sportinės veiklos pagrindą, o šiuolaikinis olimpizmas ypač veikia mūsų apmąstymus.

Tikslas – palyginti du gyvenimo būdus ir aiškiai apibūdinti jų ryšį; išsiaiškinti asketizmo vaidmenį sporto srityje ir integruoti abu gyvenimo būdus į prasmingą visumą.

Metodai. Tyrimo metodologija yra filosofinė, ją sudaro konceptualioji analizė, kurios rezultatai taikomi sporto praktikoje.

Rezultatai. Paprastatai į abi koncepcijas žiūrima kaip į priešingas arba poliariškas. Atlikta analizė leidžia teigti, kad tarp jų yra dialektinis ryšys su daugeliu tarpinių grandžių ir „tiltų" tarp jų. Dvasinės ir moralinės dimensijos yra svarbios pagrindiniams apmąstymams.

Aptarimas ir išvados. Daug autorių įspėja, kad tarp sporto ir asketizmo yra glaudus ryšys. Hedonizmo vaidmuo mažiau nagrinėjamas. Tyrimu stengtasi rasti pusiausvyrą šioje integruotos visumos struktūroje. Šiai temai reikia suteikti daugelį reikšmių. „Protingasis asketizmas" gali būti vienas iš šiuolaikinio sporto egzistencijos pagrindų šiame postmoderniame pasaulyje, stipriai orientuotame į hedonizmą.

Raktažodiai: asketizmas, Pjero de Kuberteno nuostatos, hedonizmas, gyvenimo prasmė.

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THE ANALYSIS OF PROPRIOCEPTION ALTERATION DURING FIRST FIVE MONTHS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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ABSTRACT

Research background and hypothesis. Proprioception is important in the prevention of injuries as reduced proprioception is one of the factors contributing to injury in the knee joint, particularly the ACL. Therefore, proprioception appears not only important for the prevention of ACL injuries, but also for regaining full function after ACL reconstruction.

Research aim. The aim of this study was to understand how proprioception is recovered four and five months after anterior cruciate ligament (ACL) reconstruction.

Research methods. The study included 15 male subjects (age – 33.7 ± 2.49 years) who had undergone unilateral ACL reconstruction with a semitendinosus/gracilis (STG) graft in Kaunas Clinical Hospital. For proprioceptive assessment, joint position sense (JPS) was measured on both legs using an isokinetic dynamometer (Biodex), at knee flexion of $60°$ and $70°$, and at different knee angular velocities of $2°$/s and $10°$/s. The patients were assessed preoperatively and after 4 and 5 months, postoperatively.

Research results. Our study has shown that the JPS's (joint position sense) error scores to a controlled active movement is significantly higher in injured ACL-deficient knee than in the contralateral knee (normal knee) before surgery and after four and five months of rehabilitation.

After 4 and 5 months of rehabilitation we found significantly lower values in injured knees compared to the preoperative data. Our study has shown that in injured knee active angle reproduction errors after 4 and 5 months of rehabilitation were higher compared with the ones of the uninjured knee. Proprioceptive ability on the both legs was independent of all differences angles for target and starting position for movement. The knee joint position sense on both legs depends upon the rate of two different angular velocities and the mean active angle reproduction errors at the test of angular velocity slow speed was the highest compared with the fast angular velocity.

Discussion and conclusions. In conclusion, our study shows that there was improvement in mean JPS 4 and 5 months after ACL reconstruction, but it did not return to normal indices.

Keywords: knee joint, joint position sense, angular velocity, starting position for movement.

INTRODUCTION

Proprioception is the sum of kinaesthesia and joint position sense. Kinaesthesia is defined as the awareness of joint movement and it is dynamic. Joint position sense (JPS) is restricted to the awareness of the position of a joint in space and is a static phenomenon. Proprioception can also be defined as the cumulative neural input to the central nervous system from specialized nerve endings called mechanoreceptors (Grob et al., 2002). These are located in the joint capsules, ligaments, muscles, tendons, and skin (Lephart et al., 1998; Kavounoudias et al., 2001). Some of these receptors (for example, Pacinian corpuscles) are stimulated in the initial and terminal stages of the

range of movement of joints as well as during rapid changes in velocity and direction (kinaesthesia). On the other hand the Ruffini end organ-like receptors and Golgi tendon organ-like receptors have been associated with a response to the relative position of muscles and joints (joint position sense). However, in the literature the terms kinaesthesia, joint position sense (JPS) and proprioception are often used synonymously (Grob et al., 2002). Histologically, it has been demonstrated that the human anterior cruciate ligament (ACL) contains mechanoreceptors that can detect changes in tension, speed, acceleration, direction of movement, and the position of the knee joint (Borsa et al., 1997). Proprioception is assessed by measuring kinesthetic sensibility and joint position sensibility which are perception of joint motion and joint position, respectively (Dhillon et al., 2011). Proprioception is important in the prevention of injuries as reduced proprioception is one of the factors contributing to injury in the knee, particularly the ACL. Although the causes of ACL injury are multi-factorial, poor proprioception is one of the key causative factors (Griffin et al., 2000). Therefore, proprioception appears not only important for the prevention of ACL injuries, but also for regaining full function after ACL reconstruction. Injury to the anterior cruciate ligament not only causes mechanical instability but also leads to a functional deficit in the form of diminished proprioception of the knee joint (1992; Pap et al., 1999; Fischer-Rasmussen, Jensen, 2000; Dhillon et al., 2011). Proprioception is emerging as an important factor determining post operative results of ACL reconstruction (Dhillon et al., 2011). Although reconstruction is successful in regaining joint stability, the recovery of proprioceptive function remains debatable (Henriksson et al., 2001). P. B. MacDonald et al. (1996) reported no significant improvement in proprioceptive deficits in patients 31 months after ACL reconstruction by measuring kinesthesia. Furthermore, D. M. Hopper et al. (2003) reported no significant difference in knee proprioception after 12 and 16 months of ACL reconstruction by measuring JPS. However, B. Reider et al. (2003); and S. Karasel et al. (2010) reported a significantly improved level of proprioception by measuring JPS in an ACL reconstructed knee after six months of rehabilitation when compared with the contralateral limb. The aims of this study was to understand how proprioception is recovered four and five months after ACL reconstruction. Perhaps proprioception can return to normal within 4–5 months of ACL

reconstruction. Secondly, we hypothesized that proprioceptive ability in the knee depends upon the rate at all different angles for the target and the starting position for movement. Lastly, the purpose of this study was to analyze the knee joint position sense in different knee angular velocities and to compare the results.

RESEARCH METHODS

Subjects. The group of patients included 15 male (age = 33.7 ± 2.49 years, body weight = 78.93 ± 4.31 kg, height = 177.93 ± 3.37 cm (mean ± SD)) subjects who had undergone unilateral ACL reconstruction with a semitendinosus/ gracilis (STG) graft in Kaunas Clinical Hospital. Individuals were eligible for inclusion in the experiment if they had no previous ACL surgery normal contralateral hip and ankle joint function.

Each subject read and signed a written informed consent form, consistent with the principles outlined in the Declaration of Helsinki. All subjects gave informed consent according to the requirements of the Kaunas Regional Ethical Committee of Biomedical Research (the Protocol No. BE-230). The patients were assessed preoperatively and after four and five months, postoperatively. The uninjured contralateral knee of these patients was used as an internal control.

The logic of the research. Proprioception was evaluated at the knee with the passive extension active replication method using the isokinetic dynamometer „*Biodex System* PRO 3" (ISO 9001 EN 46001, New York). The subjects sat upright in the dynamometer chair and were tied up with chest, waist and thigh straps. The axis of rotation of the dynamometer was visually aligned with the axis of rotation of the subject's knee joint. The ankle pads were placed just above the subject's lateral malleoli. The subjects were instructed to keep their hands crossed in front of their chest during all testing sessions.

I Assessment of joint position sense. The subjects were with a blindfold. They sat in the dynamometer chair and began the test in the position with the leg flexed at 90 degrees. The subjects had a handheld device with a red button. The persons leg was passively extended by the technician, at a rate of approximately 2- and 10- degrees per second, to an index angle of 60 degrees flexion. The angle was maintained for 10 seconds and the subject was asked to concentrate on its position. The knee was returned passively to the starting position and then

moved again by the motor at a speed of 2- and 10- degrees per second. When the subject thought that the leg was in the same position as before, he pressed the red button on the handheld device. The difference in degrees between the starting index angle and the reproduced angle reflected the subject's ability to estimate angular motion accurately (lower number = better proprioceptive acuity). The subjects underwent 3 repetitions at each angle and the results were evaluated as the mean absolute error of the trials. Improvements in proprioception were calculated as the difference between baseline and follow-up measures.

II Assessment of joint position sense. The subjects were with a blindfold. They sat upright in the dynamometer chair and began in the position with the leg flexed at 10 degrees. The subject's leg was passively flexed by the technician, at a rate of approximately 2- and 10- degrees per second, to an index angle of 70 degrees flexion. The angle was maintained for 10 seconds and the subject was asked to concentrate on its position. The knee was returned passively to the starting position and then moved again by the motor at a speed of 2- and 10- degrees per second. Subjects had a handheld device with a red button. When the subject thought that the leg was in the same position as before, he pressed the red button on the handheld device. Assessment of joint position sense was performed in the same way as before-mentioned.

Statistical analysis. Descriptive data are presented as means ± standard deviation (SD). Data were analyzed using a repeated measures analysis of variance (ANOVA) with time as the repeated measures factor for the outcome measures at the 4- and 5-month follow-ups. SPSS (SPSS Inc., Version 10.0, Chicago, IL) was used to calculate the ICC. The difference between the injured and uninjured knees was analyzed using one way ANOVA. The t-test for paired samples was used to determine whether there was a difference between the mean values for the same measurements on the operated and normal knee joints. The difference of $p < 0.05$ between the means of the same measurements for the operated and normal knees was considered to be statistically significant.

RESEARCH RESULTS

Joint position senses (JPS) of the knees were determined by measuring the ability of the patient to reproduce active position at two different target angles and movement start angles from 90° flexion to 60° flexion and at 10° flexion to 70° flexion, and at two different angular velocities 2°/s and 10°/s. The results of this study indicated, that there was a significant difference ($p < 0.001$) between the injured and the healthy legs before surgery and after four months, and five months $p < 0.05$ of rehabilitation (Table 1). Both the knee tests extension and flexion data showed that there was JPS error scores higher on the injured knee compared with the uninjured knee. We found that before surgery there was higher difference for JPS errors scores between the legs compared with the values four and five months after surgery. After four and five months of rehabilitation we found significantly lower ($p < 0.05$) values in the injured knees compared with the preoperative data (Table 2). In injured knee

Table 1. **Differences of degrees in JPS for mean error scores between injured and uninjured knees**

Test	Injured and uninjured knees			
	Extension		Flexion	
	Angular velocity 2°/s	Angular velocity 10°/s	Angular velocity 2°/s	Angular velocity 10°/s
Before surgery, %	56.2#	56.9#	53.9#	48.6#
After 4 months, %	40.4#	42.3#	30.8*	33.9*
After 5 months, %	30.8*	32.2*	21.1*	29.4*

Note. * – p < 0.05; # – p < 0.001.

Table 2. **The effects of improvement of degree in JPS for mean error scores on the injured knee after four and five months of rehabilitation compared with the preoperative data**

Improvement of degree	Injured knee			
	Extension		Flexion	
	Angular velocity 2°/s	Angular velocity 10°/s	Angular velocity 2°/s	Angular velocity 10°/s
After 4 months, %	23.1*	20.7*	30.3*	19.2*
After 5 months, %	37.8*	35.6*	43.9*	30.1*

Note. * – p < 0.05.

active angle reproduction errors after five months of rehabilitation, were significantly ($p < 0.05$) higher compared with uninjured knee. On both legs significant differences ($p < 0.05$) between two different angular velocities 2°/s and 10°/s (Figures 1, 2) were measured. It should be noted, that the mean active angle reproduction errors the test of angular velocity of 2°/s were the highest compared with the angular velocity of 10°/s (Table 3). There were no significant differences in both legs at all different angles for the target and the starting position of the movement.

DISCUSSION

Our study has shown that the JPS (joint position sense) error scores to a controlled active movement are significantly higher in injured ACL-deficient knee than in the contralateral knee (normal knee) before surgery and after four and five months of rehabilitation.

Before surgery we found that there were higher differences for JPS errors scores between injured ACL-deficient knee and the contralateral knee (normal knee). Many authors have demonstrated significant proprioceptive deficits in ACL-deficient knees (Pap et al., 1999; Fischer-Rasmussen, Jensen, 2000; Anders et al., 2008; Dhillon et al., 2011). Significant data have come to light demonstrating proprioceptive differences between normal and injured knees, and often between injured and reconstructed knees (Dhillon et al., 2011). R. L. Barrack et al. (1989) found that proprioception was virtually identical in the two knees of the control group. The test group, however, showed a significantly lower proprioceptive activity in injured knees as compared to the uninjured knees.

Table 3. **Differences of degrees in JPS for mean error scores (averages ± SD) between two different angular velocities of 2°/s and of 10°/s**

Angular velocity	Injured knee			Uninjured knee		
	Before surgery (averages ± SD)	After 4 months (averages ± SD)	After 5 months (averages ± SD)	Before surgery (averages ± SD)	After 4 months (averages ± SD)	After 5 months (averages ± SD)
Extension of 2°/s	16.7 ± 2.8	12.9 ± 3.3	10.4 ± 2.1	7.3 ± 1.3	7.7 ± 1.4	7.2 ± 1.3
Extension of 10°/s	12.5 ± 2.5	9.9 ± 2.2	8.1 ± 2.4	5.4 ± 1.8	5.7 ± 1.2	5.5 ± 1.4
Difference of degrees, %	25.1*	22.7*	22.4*	26.4*	25.2*	24.1*
Flexion of 2°/s	15.2 ± 5.5	10.6 ± 1.9	8.5 ± 1.9	7 ± 1.6	7.3 ± 1.2	6.7 ± 1.1
Flexion of 10°/s	9.7 ± 2.8	7.9 ± 1.5	6.8 ± 0.9	5 ± 1.6	5.2 ± 1.3	4.8 ± 0.9
Difference of degrees, %	36*	25.8*	20.3*	28.6*	29.1*	28.7*

Note. * – $p < 0.05$.
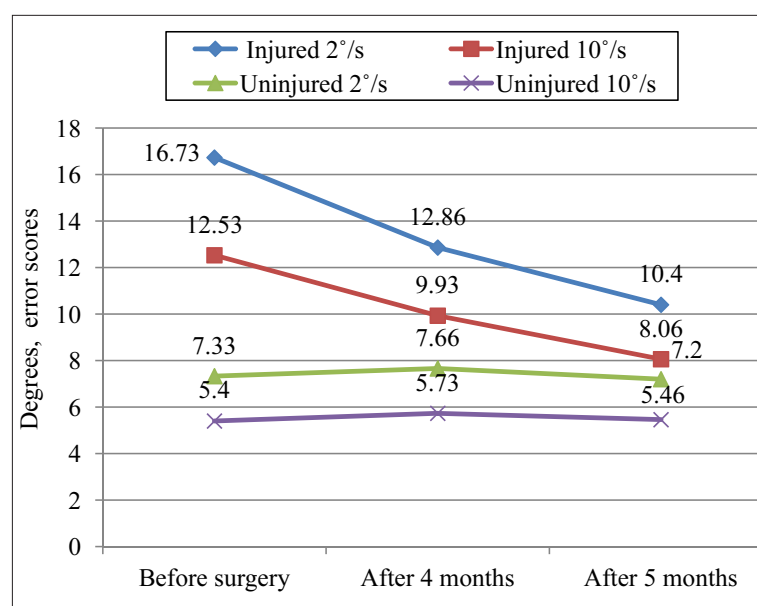
Figure 1. **Mean values of uninjured and injured knee extension at different velocities ($p < 0.05$)**

Figure 2. **Mean values of uninjured and injured knee flexion at different velocities (p < 0.05)**
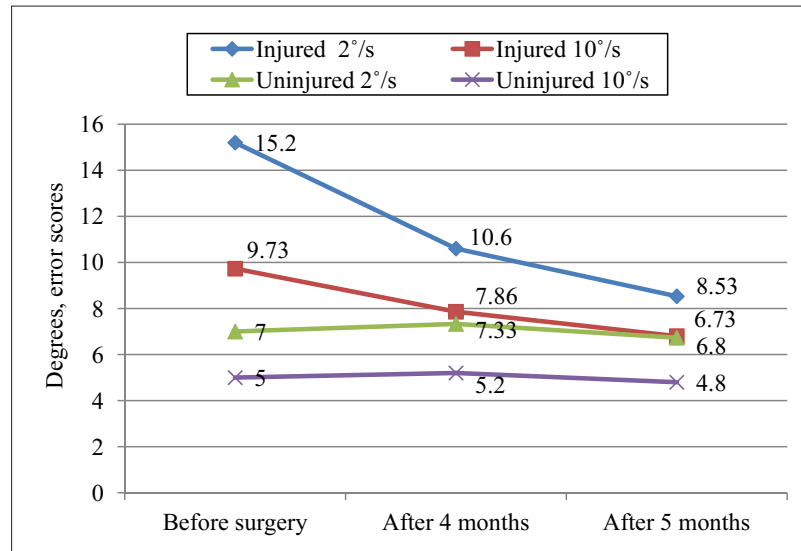
After four and five months of rehabilitation we found significantly lower values in injured knees compared with the preoperative data. Some studies concluded that proprioception might be restored to an equal level compared to the uninjured contralateral limb or controls (Reider et al., 2003; Karasel et al., 2010). ACL reconstruction alters proprioception of the knee to a certain extent; many authors have demonstrated that reconstruction of ACL restores proprioception and kinesthesia equivalent to that of ACL intact knees (Reider et al., 2003; Mir et al., 2008; Muaidi et al., 2009; Angoules et al., 2011).

In a recent study, A. G. Angoules et al. (2011) prospectively studied knee proprioception following ACL reconstruction in 40 patients, allocated into two equal groups based on reconstruction using hamstring or bone-patellar tendon-bone autograft. Joint position sense at various knee angles and threshold to detection of passive motion at 15° and 45° were used as measures of proprioception. The patients were assessed preoperatively and at 3, 6 and 12 months, postoperatively. The uninjured contralateral knee of these patients was used as an internal control. At 6 and 12 months, no statistical difference was found in the proprioceptive acuity of the reconstructed knee and uninjured knee, or in the two graft groups. The authors concluded that knee proprioception returned to normal within 6 months of ACL reconstruction, without statistically significant differences between types of autograft used. Our study has shown that in injured knee active angle reproduction errors after 4 and 5 months of rehabilitation, were significantly ($p < 0.05$) higher compared with uninjured knee.

We chose to measure JPS with the knee positioned at 10° of flexion because the ACL, as well as the posterior aspect of the joint capsule, acts as limit detectors for the neuromuscular system. This is based on the fact that neurophysiological experiments have shown increased afferent impulse generation from mechanoreceptors with joint movement into extension and that proprioception is improved at the limit of joint motion (Lephart et al., 1992). There were no significant differences of both legs at all different angles for the target and the starting position for movement.

G. Pap et al. (1999) have suggested that the analysis of failure of JPS is essential since differences between damaged and undamaged knees can be seen in a wide range at different angular velocities. Therefore, in this study we analyzed failure of JPS at each of the two different angular velocities used. We used reproduction active position (RAP) to assess the proprioceptive function in ACL- reconstructed and normal knees. We preferred this method because reproductions are done actively using muscular contractions of muscle groups during RAP, thus enabling elicitation of input from the musculotendinous receptors as well (Borsa et al., 1997). Although it is usually performed at slow speeds, RAP stimulates both joint and muscle receptors and provides a more functional assessment of the afferent pathways (Lephart et al., 1992). Our study has shown that significant differences between two different angular velocities 2°/s and 10°/s were measured on both legs. It should be noted that the mean active angle reproduction errors in the test of angular

velocity of 2°/s were highest compared with the angular velocity of 10°/s. This is in accordance with previous studies in which proprioceptive acuity was found to improve with increasing velocities of joint movement (Pap et al., 1997). G. Pap et al. (1997) found increasing rates of failure for the detection of both the start and the end of movement with slower angular velocities. Two explanations may account for this: 1) separated populations of mechanoreceptors in the ACL are stimulated at different rates of extension of the knee, providing different proprioceptive information; or 2) periarticular receptors (including muscle spindles) may be selectively activated at higher speeds (Wright et al., 1994).

CONCLUSIONS AND PERSPECTIVES

In conclusion, our study shows that there was improvement in the mean JPS four and five months after ACL reconstruction, but it did not return to normal. Proprioceptive ability on both legs was independent of all different angles for the target and the starting position for movement. The knee joint position sense on both legs depends upon the rate between two different angular velocities, and the mean active angle reproduction errors at the test of angular velocity at slow speed were the highest compared with the fast angular velocity.

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PROPRIORECEPCIJOS POKYČIAI PER PIRMUOSIUS PENKIS MĖNESIUS PO KOJŲ PRIEKINIŲ KRYŽMINIŲ RAIŠČIŲ REKONSTRUKCIJOS

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Proprioscepcija yra svarbi traumų prevencijai. Pablogėjusi proprioscepcija yra vienas iš veiksnių, kuris gali sukelti kelio sąnario traumą, ypač priekinio kryžminio raiščio (PKR). Proprioscepcija yra svarbi ne tik traumų prevencijai, bet ir visaverčiam kelio funkcijos atgavimui įvertinti po atliktos PKR rekonstrukcijos.

Tyrimo tikslas – nustatyti proprioscepcijos pokyčius praėjus 4 ir 5 mėnesiams po atliktos PKR rekonstrukcijos.

Metodai. Buvo tiriama 15 vyrų (amžius – 33,7 ± 2,49 m.), kuriems Kauno klinikinėje ligoninėje buvo atlikta vieno kelio PKR rekonstrukcija panaudojant pusgyslinio/grakščiojo raumens sausgyslės transplantą. Tiriant proprioscepciją, kelio sąnario pozicijos nustatymas buvo matuojamas izokinetiniu dinamometru (*Biodex*), tiriamajam lenkiant kelio sąnarį skirtingais kampais (60° ir 70°) ir skirtingais kampiniais greičiais (2 ir 10°/s). Tiriamieji buvo testuojami prieš operaciją ir praėjus 4 ir 5 mėnesiams po jos.

Rezultatai. Tyrimas parodė, kad prieš operaciją bei po 4 ir 5 mėnesius trukusios reabilitacijos kelio sąnario pozicijos nustatymo daromų klaidų reikšmės yra didesnės tos kojos, kurios nutrauktas priekinis kryžminis raištis, lyginant su sveiko kelio reikšmėmis. Po 4 ir 5 mėnesių reabilitacijos nustatytas sumažėjęs pažeistos kojos daromų klaidų vidurkis, lyginant su duomenimis prieš operaciją, bet jie vis dar liko didesni nei sveikos kojos. Abiejų kojų proprioscepcija nepriklausė nuo skirtingų kelio sąnario sulenkimo kampų ir skirtingos judesio pradžios, priklausė – nuo skirtingų kampinių greičių. Sąnario kampo nustatymo klaidų buvo daroma mažiau testuojant dideliu kampiniu greičiu nei mažu.

Aptarimas ir išvados. Atlikus PKR rekonstrukciją, po 4 ir 5 mėnesių reabilitacijos kelio sąnario pozicijos nustatymas pagerėjo, bet negrįžo iki normos rodiklių.

Raktažodžiai: kelio sąnarys, sąnario pozicijos nustatymas, kampinis greitis, judesio pradžios pozicija.

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RELATIONSHIP BETWEEN SPORTS EXPERIENCE AND ANTHROPOMETRIC INDICES AND SPORT PERFORMANCE IN WORLD WOMEN'S HANDBALL CHAMPIONSHIP'2009

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ABSTRACT

Research background and hypothesis. The increasing demand for ever higher top level has meant greater interest and research into the factors which influence performance and sporting achievements. Handball is a complex sport whereby performance can be analyzed and presented in a variety of ways. We hypothesized that teams with players with higher anthropometric indices and greater sporting experience had better possibilities in winning a match-play.

Research aim was to assess the interaction between players' height, body mass, body mass index (BMI), age, sports experience and sport performance in the World Women's Handball Championship'2009 (WWHC'2009).

Research methods. The data sets were collected from the IHF website (http//www.ihf.info). We analyzed the height, body mass, body mass index (BMI), sporting experience (international matches played and goals scored) of 390 players as well as their influence on winning points (Pearson's correlation) and final ranking position (Spearman's Correlation) of WWHC'2009.

Research results. Champions from Russia, the first four seat players and European women players were greater in body size (height, body mass), and sports experience.

Discussion and conclusions. Teams composed of players with greater experience had more possibilities to win (r = 0.719; p < 0.001; Y = 0.1571x + 4.9104; r² = 0.5183), but body mass had negative influence (r = 0.317; Y = 0.5353x – 25.598; r² = 0.1008) as well as BMI (r = –0.3300.; Y = –2.0762x + 57.273; r² = 0.1089). The height of players had moderate influence (r = 0.551; p < 0.001) on wining a match-play. It should be noted that the players in the last elite-level competition (European Women's Handball Championship'2010) showed the same tendency and were taller and heavier than the players of WWHC'2009.

Keywords: Women's Handball, body mass, height.

INTRODUCTION

Athletes with specific body structure characteristic of a particular sport have gained significant achievements in sports (Norton, Olds, 2001). However, considering the development of sports and the permanent changes of athletes in the national teams, it is necessary to study the changes in athletes' body composition permanently (Jones et al., 2008).

It has been asserted that handball players' physique (body mass, height) as well as of those in other sports, has a significant impact on athletic outcomes (Bayios et al., 2006; Massuca, 2011; Michalsik et al., 2011). However, the results are sometimes quite controversial, unique to the sample of high skilled or elite athletes. The influence of anthropometric indicators (height, body mass) on sports performance in elite sport might be at different levels: moderate or even insignificant (Bezerra, Simão, 2006). For this reason, it is necessary to establish the trends of interaction between body composition and sport performance permanently.

To date, most of the literature on team handball focuses on elite men's handball players' anthropometric characteristics, competition experience and their interaction with athletic performance. Only a few studies have evaluated peculiarities and tendencies of sport performance in elite women's handball. However, there is no publication related to the last Women's World Handball Championship'2009 (WWHC'2009). It is highly important to find out the influence of body composition (height and body mass, body mass index [BMI]), age, sports experience (international matches played and the goals scored) indicators on sport performance; thus, to carry out discriminant analyses between winners and losers in elite women modern handball.

The hypothesis. The team whose players were higher, had greater body mass and sports experience had better possibilities in winning the match and rank in WWHC'2009.

The aim of the study was to assess the peculiarities of sport performance in WWHC'2009 and the influence of player's body composition, age, sports experience on sport performance.

RESEARCH METHODS

The data sets were collected from the International Handball Federation (IHF) website (http//ww.ihf.info) cover database of the WWHC'2009. We used the data about 24 teams with 390 players, their anthropometric characteristics (height, body mass and body mass index), age, sports experience (international matches played and the goals scored). Body mass index (BMI) was calculated by the formula (Carter, 1984) BMI = body mass (kg)/height^2 (m). The indicators of champions, teams winning of 1–4, 5–12 and 13–24 places, and between teams representing continents were compared. The level of significance was conducted at $p < 0.05$, and the magnitude between values was assessed by using standard effect size (*ES*) analysis procedures (Hopkins, 2006) using previously established scales (Hopkins, 2002): trivial < 0.2, small 0.2–0.6, moderate 0.6–1.2, large 1.2–2.0, very large > 2.0. Pearson's product moment correlation was used to examine the relationships between the analysed indicators and winning points, and Spearman's correlation coefficient was used to evaluate relationships in ranking places. The indicators of champions, teams winning 1–4, 5–12 and 13–24 places, and between have representing different continents were

compared using a general linear model analysis of variance (ANOVA), with Tukey Post Hoc test using Excel 2003 and statistical package SPSS 17.0.

RESEARCH RESULTS

Height. The height was typical of teams which took higher places in the ranking scale (Table 1, 2). The champions – Russian players ($p < 0.01$; ES = 0.850 [moderate]), the players of 1–4 teams ($p < 0.01$; ES = 0.450 [small]), and European handball players ($p < 0.001$; ES = 0.349 [small]) were higher than the tournament player on average (Table 1). Players of 13–24 teams ($p < 0.01$; ES = 0.252 [small]), players of Africa ($p < 0.02$; ES = 0.320 [small]), and America ($p < 0.01$; ES = 0.437 [small]) continents were smaller than the tournament player on average. Russian players exceeded the players of the lowest 5–12 teams ($p < 0.01$; ES = 0.746 [moderate]), and of 13–24 teams ($p < 0.001$; ES = 1.085 [moderate]) in the ranking scale. African ($p < 0.001$; ES = 1.218 [large]), American ($p < 0.001$; ES = 1.27 [moderate]), Asian ($p < 0.001$; ES = 1.015 [moderate]), Australian ($p < 0.01$; ES = 0.957 [moderate]) and European handball players ($p < 0.05$; ES = 0.545 [small]) were smaller than Russian players. Players of 1–4 teams were taller than players of 5–12 ($p < 0.05$; ES = 0.309 [small]) and of 13–24 ($p < 0.001$; ES = 0.703 [moderate]) teams, as the players of 5–12 teams ($p < 0.001$; ES = 0.436) compared to the lowest (13–24) ones. European handball players were significantly taller ($p < 0.001$) compared to handball players of the continents of Africa (ES = 0.707 [moderate]), America (ES = 0.804 [moderate]) and Asia (ES = 0.540 [small]), but not significantly higher ($p > 0.05$; ES = 0.416 [small]) than the players of Australian continent.

Body mass. Variation of body mass was opposite to the height (Table 1, 2). Teams including players with the heavier body mass took lower places. Asian handball players had statistically significantly ($p < 0.01$; ES = 0.365 [small]) lower body mass than the tournament player on average. Russian players were heavier in their body mass than the players of 5–12 teams ($p < 0.02$; ES = 0.613 [moderate]), Asian ($p < 0.01$; ES = 0.883 [moderate]) and American handball players ($p < 0.05$; ES = 0.333 [small]). The players of 1–4 teams were heavier in their body mass ($p < 0.05$; ES = 0.373 [small]) than players of 5–12 teams. European handball players were heavier ($p < 0.001$; ES = 0.548 [small]) compared to players of the Asian continent, but

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not significantly (p > 0.05) compared to players of other continents. Asian handball players had less body mass (p < 0.01; ES = 0.503 [small]) compared to players of the African continent.

Body mass index. BMI indicator was adequate to body mass (Tables 1, 2). BMI of Asian players (p < 0.01; ES = 0.349 [small]) and players of lower 5–12 teams were smaller (p < 0.01; ES = 0.286 [small]) than that of the tournament player on average. BMI of African players were higher (p < 0.001; ES = 0.489 [small]) than that of the tournament player on average. Players of 5–12 teams had lower (p < 0.001; ES = 0.482 [small]) BMI than players of 13–24 teams. African handball players had greater BMI than Russian handball players (p < 0.05; ES = 0.773 [moderate]). BMI of African players (p < 0.01; ES = 0.642 [moderate]) and American (p < 0.02; ES = 0.056 [trivial]) players were less compared to the ones of players of the European continent. BMI of Asian handball players were significantly less (p < 0.001) compared to the ones of players of Africa (ES = 0.815 [moderate]) and America (ES = 0.090 [trivial]).

Age. African handball players were older (p < 0.01; ES = 0.350 [small]), Asian handball players were younger (p < 0.02; ES = 0.318 [small]) than

the tournament player on average. The players of 1–4 teams were older than players of 5–12 teams (p < 0.05; ES = 0.301 [small]). European handball players were significantly older than the Asians (p < 0.001; ES = 0.495 [small]), Americans (p < 0.05; ES = 0.380 [small]) and Australians (p < 0.05; ES = 0.504 [small]), but not significantly older (p > 0.05) than the Africans. African handball players were older than Asian (p < 0.001; ES = 0.659 [moderate]), Australian (p < 0.02; ES = 0.649 [moderate]) and American (p < 0.01; ES = 0.567 [small]) handball players, but insignificantly older than European players (p > 0.05).

Sports experience (international matches played). The players of 1–4 teams (p < 0.02; ES = 0.312 [small]) and European (p < 0.05; ES = 0.205 [small]) handball players had played more international matches than the tournament player on average (Tables 1, 2). Players of lowest 13–24 teams (p < 0.01; ES = 0.284 [small]) and Australian (p < 0.01; ES = 1.051 [moderate]) handball players had played fewer international matches than the tournament player on average. Russian players had played more international matches than Australian players (p < 0.01; ES = 1.307 [large]). Players of the lowest 13–24 teams had played significantly fewer

Table 1. **Body size, sports experience of players of different continents and ranking scale at WWHC'2009 ($\bar{x} \pm s$)**

Players	Height, cm	Body mass, kg	BMI	Age, years	International matches played	Goals scored
Mean, n = 390	174.6 ± 7.1	68.4 ± 7.9	22.1 ± 1.1	24 ± 3.7	46 ± 47	111 ± 146
Champions, n = 16	180.5 ± 6.7 ***	72.3 ± 7.5	22.4 ± 1.9	24 ± 3.7	53 ± 44	136 ± 155
1–4th places, n = 67	177 ± 6.3 ***	70.6 ± 7.5	22.3 ± 1.8	25 ± 3.8	62 ± 54 **	149 ± 149
5–12th places, n = 133	175.7 ± 6 &&&	67.8 ± 7	21.9 ± 1.6 ***	24 ± 3.8	51 ± 48	121 ± 153
13–24th places n = 190	172.7 ± 7.5 ***&&&&	68.2 ± 8.4 &&	22.8 ± 2	24 ± 4.2	34 ± 40 ***	84 ± 128
European continent players, n = 179	177 ± 6.3 ****&	69.6 ± 6.9	22.2 ± 1.5	25 ± 3.7	56 ± 50 *	133 ± 148
Asian continent players, n = 83	173.2 ± 7.7 &&&& @@@@	65.5 ± 7.9 ***&&& @@@@	21.8 ± 1.7 ***	23 ± 4 ***@@@@	35 ± 43 @@@	81 ± 128 @
American continent players, n = 48	171.4 ± 7.5 ***&&&& @@@@	69.8 ± 7.4 &	23.4±2.3 @@	23±3.2 @	47 ± 33	193 ± 67
African continent players, n = 66	172.4 ± 6.5 **&&&& @@@@	69.8 ± 9.2	22.9±1.7 **** &&&&@@@	25±4.2 **	34 ± 49 @@@	101 ± 193
Australian continent players, n = 14	174.4 ± 6 &&&	68.7 ± 8.8	22.5 ± 2.2	22 ± 5 @	10 ± 20 ***&&& @@@@	16 ± 26 *&& @@@@

Note. * – p < 0.05; ** – p < 0.02; *** – p < 0.01; **** – p < 0.001 compared with the average value; & – p < 0.05; &&& – p < 0.01; &&&& – p < 0.001 compared with champion's value; @ – p < 0.05; @@ – p < 0.02; @@@ – p < 0.01; @@@@ – p < 0.001 compared with European value.

Table 2. **Body size, sports experience of players of different teams at WWHC'2009 ($\overline{x} \pm s$)**

Country	Height, cm	Body mass, kg	BMI	Age, years	Sports experience	
					International matches played	Goals scored
Russia	180.5 ± 6.7***	72.3 ± 7.5	22.1 ± 1.1	24 ± 3.7	53 ± 44	136 ± 155
France	177 ± 5.9	69.2 ± 7.5	21.9 ± 1.9	24 ± 3.8	51 ± 44****	110 ± 93**
Norway	178.1 ± 4.9*			26.6 ± 3*	87 ± 70	204 ± 198
Spain	175.1 ± 7.1	70.4 ± 7.6	22.9 ± 2.2	26 ± 4.6	57 ± 49	144 ± 175
Denmark	175.5 ± 6.1	70.6 ± 7.1	22.8 ± 1.3	25 ± 3.9	54 ± 40	98 ± 46
Korea	172.4 ± 5.4	62.3 ± 6.4***	20.9 ± 1.4***	24 ± 4.4	67 ± 51**	182 ± 179
Germany	176.2 ± 7.5	69.6 ± 6.8	22.4 ± 1.4	25 ± 2.4	76 ± 59	126 ± 118
Romania	177.3 ± 4.6	69.7 ± 6.2	22.1 ± 1.6	26 ± 3.2*	65 ± 47	201 ± 207*
Hungary	176.8 ± 5.7	67.6 ± 6.3	21.5 ± 1.3	23 ± 3	34 ± 38	85 ± 126
Austria	174.5 ± 5.8	66 ± 6.4	21.6 ± 1.4	21 ± 3.9***	52 ± 52	139 ± 199
Angola	174 ± 6.9	69 ± 9.7	22.7 ± 2.3	24 ± 3.3	15 ± 28***	10 ± 28**
China	178.8 ± 4.7**	68.1 ± 4.7	21.3 ± 1	22 ± 3.5*	47 ± 40	
Sweden	177 ± 5.8	71.7 ± 6.1	22.8 ± 1	25 ± 3	55 ± 49	120 ± 116
Tunisia	172 ± 6	65.3 ± 6.5	22 ± 1.6	23 ± 4	69 ± 69	245 ± 287***
Brazil	176.6 ± 7	70 ± 6.8	22.3 ± 1	25 ± 2.8	46 ± 38	88 ± 72
Japan	167.6 ± 5.8****	63.1 ± 4.8***	22.4 ± 1.5	25 ± 3	24 ± 28	63 ± 75
Ukraine	178.8 ± 8*	68.8 ± 7.1	21.4 ± 0.8	26 ± 4.1	28 ± 20	75 ± 71
Ivory Coast	175.3 ± 5.4	74.7 ± 9.9***	24.2 ± 2.3****	27 ± 4.1****		
Argentina	172.1 ± 5.7	67.6 ± 6.8	22.8 ± 1.3	23 ± 3.5	47 ± 28	98 ± 65
Congo	168 ± 5.8****	69.7 ± 8.5	24.6 ± 2.1****	26 ± 4.6	18 ± 9*	47 ± 26***
Thailand	166.6 ± 4.8****	61.1 ± 6.5****	21.9 ± 1.9	20 ± 2.6****	1 ± 1****	10 ± 8
Kazakhstan	179.8 ± 6.8***	72.8 ± 10.7*	22.4 ± 2.3	22 ± 4.4		
Chile	165.5 ± 5.2****	64.5 ± 8	23.5 ± 2.5**	22 ± 2.9		
Australia	174.4 ± 6	68.7 ± 8.8	22.5 ± 2.2	22.8 ± 5	10 ± 20***	16 ± 26**

Note. * – p < 0.05; ** – p < 0.02 ; *** – p < 0.01 ; **** – p < 0,001 compared with the average value.

(p < 0.001) international matches compared to the players of 1–4 teams (ES = 0.600 [moderate]) and of 5–12 teams (ES = 0.401 [small]). European players had played significantly more international matches compared to the ones of other continents (p < 0.01– 0.001; ES = small) except Australian continent (ES = 1.304 [large]) and insignificantly compared to American handball players. Australian handball players had played less international matches than the players from America (p < 0.001; ES = 1.360 [large]) and Asia (p < 0.05; ES = 0.779 [moderate]).

Sports experience (goals scored). The players of 1–4 teams had scored more goals than the players of the lowest 13–24 teams (p < 0.01; ES = 0.462 [small]) (Tables 1, 2). European handball players had scored more goals compared to players of the Asian continent (p < 0.05; ES = 0.373 [small]). Australian handball players had scored fewer goals than the player of the tournament on average (p < 0.05; ES = 1.097 [moderate]), the champions – Russian players (p < 0.02; ES = 1.317 [large]), European players (p < 0.02; ES = 1.329 [large]), and the players of America (p < 0.001; ES = 3.748 [very large]).

RELATIONSHIP BETWEEN SPORTS EXPERIENCE AND ANTHROPOMETRIC INDICES AND SPORT PERFORMANCE IN WORLD WOMEN'S HANDBALL CHAMPIONSHIP'2009

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DISCUSSION

The results of our research are in line with other researchers who have claimed that the successful outcome of the game is mainly due to handball players' physique (height, body mass) (Bayios et al., 2006; Hasan et al., 2007; Massuca, 2011; Michalsik et al., 2011) body fat and muscle ratio (Vila et al., 2011). Handball players with greater experience have a greater chance of winning a match-play (Schneider et al. 2007; Skarbalius, 2009). Such trend was established in the WWHC'2009. The players of the European continent and players representing the teams winning 1–4 places were more experienced, taller, older and heavier than the players of the WWHC'2009 on average. The same tendency was established in the last European Women's Handball Championship'2010 (Joergensen, 2010). It should be noted that the players of the European Women's Handball Championship'2010 were taller and heavier than WWHC'2009 participants. Handball players were getting taller over time (Taborsky, 2007) such as athletes in many sports have been getting taller and more massive. It could be affirmed that the handball female players were getting bigger at a faster rate than that predicted by the secular trend alone and it is in the line to athletes' development in general (Norton, Olds, 2001).

The question is how players' height and body mass, and BMI influenced sports results. The height of players was a significant indicator to win a match–play ($r = 0.551$; $p < 0.001$; $Y = 0.7627 x - 121.93$; $r^2 = 0.3043$) (Figure 1). As the competition system of the WWHC'2009 was divided into stages (preliminary, main round, and final) with different mastership level of participating teams, it did not allow teams to take the highest places ($r = -0.278$; $p < 0.01$) in the ranking scale adequate to their mastership level. It can be concluded that the final result of match-play may be influenced by other factors (Hughes, Frank, 2006).

Contrary to the height the body mass indices had a negative impact on winning a match-play ($r = 0.317$; $p < 0.01$; $Y = 0.05353 x - 25.598$; $r^2 = 0.1008$), winning the tournament score and even to predict the championship places for the teams ($r = -0.067$) (Figure 2). In consequence, greater body mass of players was the limiting factor to win a match-play. This is controversial compared to elite men's handball (Skarbalius, 2009). Negative influence of body mass on sports results in WWHC'2009 could be explained by the phenomenon of the ratio of

muscle and fat mass in females (Hatzimanouil et al., 2005). BMI had a negative impact on winning a match-play ($r = -0.33005$; $Y = -2.0762 x + 57.273$; $r^2 = 0.1089$) and winning the tournament score ($r = -0.230$; $p < 0.01$) (Figure 3).
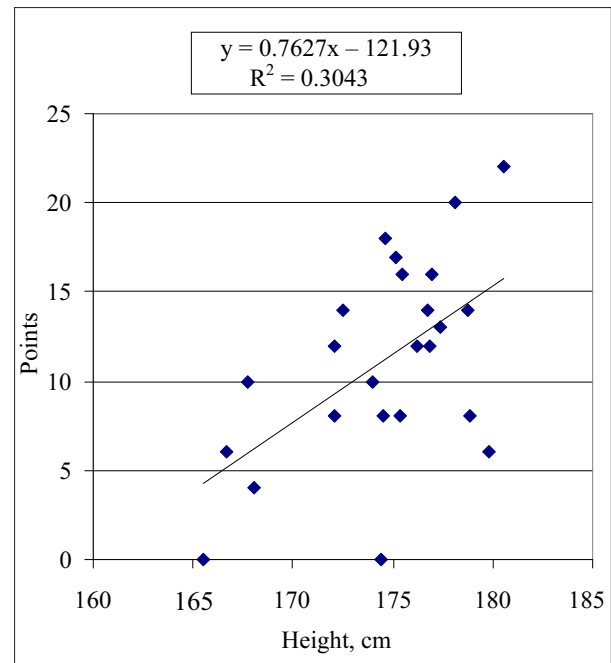
Figure 1. **Relationship between players' height and winning points in WWHC'2009**
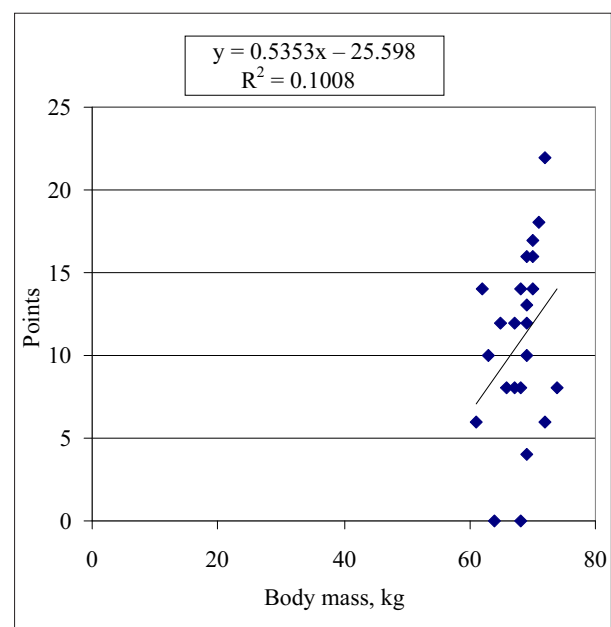
Figure 2. **Relationship between players' body mass and winning points in WWHC'2009**

High-performing athletes are characterized by sporting experience which is highly related to the age of athletes as well (Skarbalius, 2009). F. Taborsky (2011) asserts that the handball players

y = –2.0762x + 57.273
$R^2 = 0.1089$
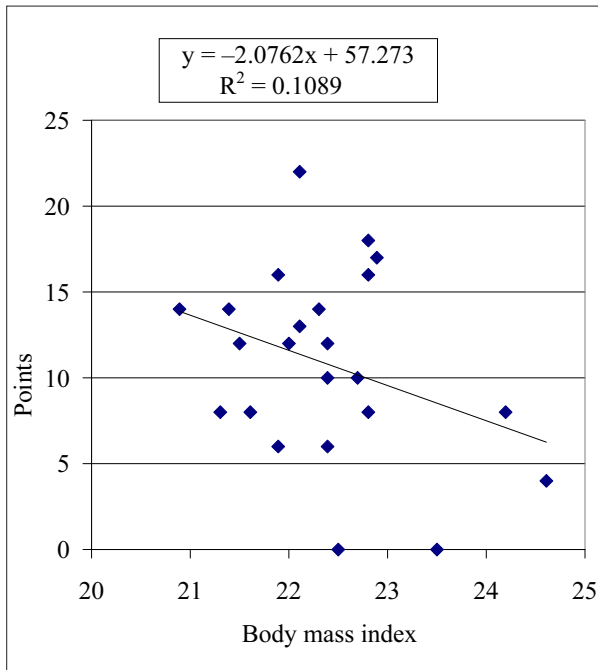
Figure 3. **Relationship between players' BMI and winning points in WWHC'2009**

greatly in fitness, but the correlation may be much lower if similar studies are conducted on a group consisting entirely of elite athletes. The results of WWHC'2009 might be considered to be in line to G. Laffaye and T. Debanne (2011) who stated that within elite handball population height or body mass did not guarantee throwing the ball quickly.

y = 0.1571x + 4.9104
$R^2 = 0.5183$
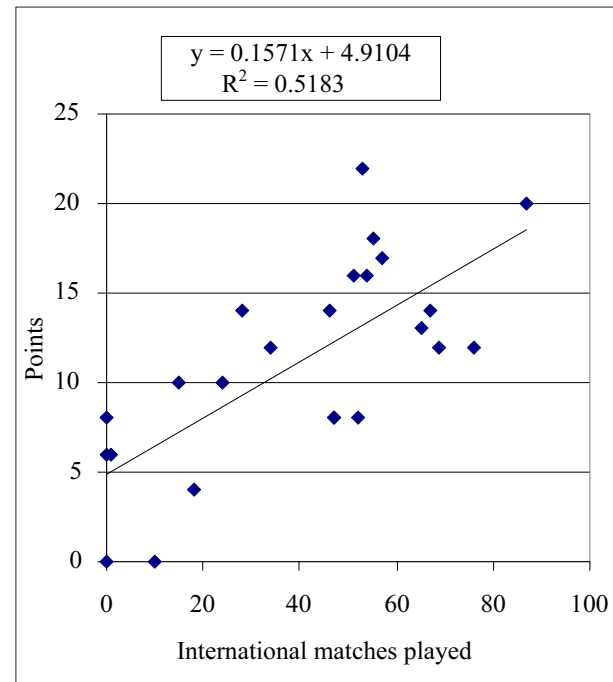
Figure 4. **Relationship between players' sports experience (international matches played) and winning points in WWHC'2009**

who participated more in high-level competitions are superior and more mentally fit. Teams, the players of which had more sports experience (international matches played), had more chances of winning a match-play (r = 0.719; p < 0.001; Y = 0.1571 x + 4.9104; r² = 0.5183) and possibilities to take higher places (r = 0.356; p < 0.01) (Figure 4). The players of the teams of higher positions (1–12) in the ranking scale had played more than 40 matches. Another indicator of sports experience (goals scored) had a significant impact on winning a match-play in the WWHC'2009 (r = 0.655; p < 0.001; Y = 0.052 x + 6.5346; r² = 0.4296) (Figure 5). One more significant indicator was the age of players for winning a match-play (r = 0.504; p < 0.001; Y = 1.5641x + 26.372; r² = 0.2547) (Figure 6). However, a weak relationship was found between the age and the final places in the ranking scale (r = –0.154, p < 0.01). Such contraversial findings might be explained by not valid enough competition system for the mastership of participating teams (while the teams were divided into groups based on subjective criteria) in WWHC'2009.

On the other hand, such controversial findings might be explained on the variation of interaction during athletes' mastership development. Researchers suggest (Mujika, 2007; Pyke, 2009) that athletes' fitness might be highly correlated with sports results in the group of people varying

y = 0.052x + 6.5346
$R^2 = 0.4296$

Figure 5. **Relationship between players' sports experience (goals scored) and winning points in WWHC'2009**

RELATIONSHIP BETWEEN SPORTS EXPERIENCE AND ANTHROPOMETRIC INDICES AND SPORT PERFORMANCE IN WORLD WOMEN'S HANDBALL CHAMPIONSHIP'2009

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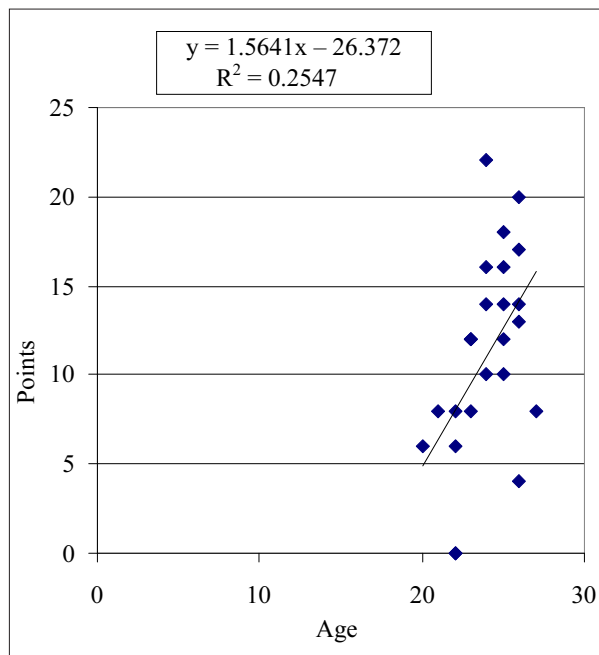
Figure 6. **Relationship between players' age and winning points in WWHC'2009**

CONCLUSIONS AND PERSPECTIVES

Older handball female players, which meant greater sports experience (international matches played and the goals scored), had more possibilities to win in the WWHC'2009.

Sports experience had higher influence than body size (height and body mass) in winning the matches played.

The indices of body mass and BMI had negative influence on winning of match-play.

Future research is needed to reveal the key discriminated indicators for sport performance between winners and losers.

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PASAULIO MOTERŲ RANKINIO ČEMPIONATO'2009 ŽAIDĖJŲ ANTROPOMETRINIŲ RODIKLIŲ, VARŽYBINĖS PATIRTIES RYŠYS SU SPORTINIAIS REZULTATAIS

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Sportininkų parengtumas lemia sportinius rezultatus. Rankinio varžybinė veikla kompleksiška, dėl to žaidimo ypatumai gali būti analizuojami įvairiais būdais. Elito rankininkių kūno sudėjimo ir sportinės patirties ryšys su sportiniais rezultatais leistų atskleisti ypatumus, būdingus ne tik konkrečioms aukščiausio rango varžyboms, bet ir sudarytų prielaidas spręsti apie elito rankinio tendencijas. Keliama hipotezė, kad komandos, kurių žaidėjos yra aukštesnės, didesnės kūno masės ir sportinės patirties, turi daugiau galimybių laimėti rungtynes.

Tikslas – nustatyti ir įvertinti 2009 metų pasaulio moterų rankinio čempionato komandų ūgio, kūno masės, kūno masės indekso (KMI), amžiaus, varžybinės patirties ryšį su sportiniais rezultatais.

Metodai. Iš viešai prieinamo Pasaulio rankinio federacijos puslapio duomenų bazės (http//www.ihf.info) atlikta paskutinio 2009 m. XIX moterų rankinio pasaulio čempionato (24 komandų) 390 žaidėjų antropometrinių rodiklių (ūgio ir kūno masės), amžiaus, varžybinės patirties (šalies rinktinei atstovautų rungtynių ir įmestų įvarčių skaičiaus) lyginamoji analizė (skirtumų patikimumas nustatytas Stjudento *t* kriterijumi taikant 95% reikšmingumo lygmenį – p < 0,05). Minėtų rodiklių ryšiui su sportiniais rezultatais (pelnytais taškais ir užimtomis vietomis) nustatyti buvo taikyti Pirsono ir Spirmeno koreliacijos koeficientai.

Rezultatai. Čempionės Rusijos žaidėjos, pirmųjų keturių vietų rankininkės ir europietės buvo aukščiausios ir didžiausios sportinės patirties.

Aptarimas ir išvados. Čempionato rungtynių sėkmę lėmė varžybinės patirties rodikliai. Didesnės patirties žaidėjos (pagal žaistų tarptautinių rungtynių rodiklį) turėjo daugiau galimybių laimėti rungtynes (r = 0,719; p < 0,001; Y = 0,1571x + 4,9104; r² = 0,5183) ir užimti aukštesnes vietas (r = –0,356; p < 0,01), tačiau neigiamą poveikį turėjo kūno masė (r = 0,317; Y = 0,5353x – 25,598; r² = 0,1008) ir KMI (r = –0,3300; Y = –2,0762x + 57,273; r² = 0,1089). Paskutinio 2010 metų Europos moterų rankinio čempionato rankininkės (www.eurohandball.com) buvo aukštesnės ir didesnės kūno masės negu PC'2009 dalyvės.

Raktažodžiai: moterų rankinis, kūno masė, ūgis.

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THE ANALYSIS OF OBJECTIVELY MEASURED WEEKLY PHYSICAL ACTIVITY OF ADOLESCENT BOYS

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ABSTRACT

Research background and hypothesis. The objective methods for measuring PA are used more and more widely in various research studies all over the world. To our best knowledge, this pilot study is the first attempt in Lithuania to objectively assess physical activity of adolescents with an ambition to develop a more accurate methodology in assessing physical activity.

Research aim of this study was to analyze the objectively measured weekly physical activity results of adolescent boys.

Research methods. The PA of schoolboys was measured using Tri-axis ActiTrainer Activity Monitors. Boys were asked to wear the monitors for the whole week. The level of the intensity of PA was determined by calculating energy consumption in METs. Based on the frequency of vigorous and moderate PA per week, the participants of this study were devided into PA groups.

Research results. All of the schoolboys experienced LPA on each of the assessed days. MPA on each day was experienced by 59.6 % of the boys. No participants achieved VPA on a daily basis. The frequency of MPA and VPA experienced most often was 5–7 and 1–3 days per week, respectively. The total PA measured during the week was largely comprised by LPA, i. e. 79.8%; MPA and VPA were 18.8 and 1.4%, respectively.

Discussion and conclusion. Boys who achieve VPA, have a greater total PA during the week than those boys who do not experience VPA. If boys achieve VPA on more than 2 days during the week, even if it is just for 10 min, there is a significant increase in the total amount of weekly PA as well as a decrease in their body mass index (BMI). Boys' who do not experience MPA at least for 6 days/week, the total amount of weekly PA decreases.

Keywords: PA frequency, PA intensity, PA volume.

INTRODUCTION

Physical activity is vital for maintaining person's health and body strength. Many diseases are related to physical inactivity, which may be a hypokinetic cause of illness (Welk, 2002). Continuous physical activity (PA) from an early childhood may improve metabolic function and regulate arterial blood pressure, which in turn may prevent from the chronic non-contagious disease risk factors (such as overweight, high blood pressure, hypercholesterolemia, etc.), and, therefore, may decrease the potential of occurrence of such chronic diseases as obesity or cardiovascular illnesses at an older age (Berenson, 2002; Gordon-Larsen et. al, 2004). There are about fifty different questionnaires available to use when assessing person's physical activity (Sallis, Saelens, 2000). Most experts suggest using the so called "golden standard" – the energy consumption – in order to determine the level of PA accurately (Sirard, Pate, 2001). In practice, physical activity and energy consumed for it are measured using heart rate and activity monitors (i. e. pedometers and accelerometers). Recently, some scientists (Dencker et al., 2006) raised doubt whether a questionnaire is a reliable tool to collect the information regarding PA. To be more precise, the reliability of the questionnaires, attempting to assess physical activity rather than

training, is under scrutiny. It is only natural that other tools such as accelerometers are being used to evaluate PA. An accelerometer, as non-invasive research equipment, can accurately estimate body movement; be useful in the labs as well as in the research field; indicate the intensity, frequency and duration of activity; deliver information at one-minute intervals. The data is easy to collect, analyze and store for long periods of time (eg. for weeks). Nevertheless, this PA assessment method has its own shortcomings (Catellier et al., 2005; Trost et al., 2005: Ward et al., 2005). For example, the cost of these tools may limit the number of subjects to be assessed. Some limitations occur when registering certain type of PA such as upper body movement, downhill walking, or activity in the water. There is also a lack of practical comparison of certain social groups with regards to energy consumption. Besides, no guarantees are available that these monitors will be carried for a prolonged period of time, when the participants of the study are not being observed. It is thought that accelerometers provide accurate assessment of the total PA, but not energy consumption, especially during the leisure time (Brage et al., 2004).

Since 2001 there have been more studies available in which the three-axial accelerometers were used to assess PA in children (Eisennman et al., 2004). The mono-axial accelerometers are usually worn, and their sensor is oriented in vertical plane. Multi-axial accelerometers are most sensitive in vertical plane, but they also sensitively react to a movement in other directions (Chen, Bassett, 2005). On the contrary, the three-axial accelerometers display the readings in each plane separately as well as integrated results (Rowlands, 2007).

Nowadays, researchers trust those methods of data analysis of speed monitor, which allows determining the type and intensity of physical activity when the activity is known (Pober et al., 2006).

The objective methods of measuring physical activity are used more and more widely in various research studies all over the world. To our best knowledge, this pilot study is the first attempt in Lithuania to objectively assess physical activity of adolescents with an ambition to develop a more accurate methodology in assessing physical activity.

The aim of this study was to analyze the objectively measured weekly physical activity results of adolescent boys.

RESEARCH METHODS

The participants of this study were 104 healthy adolescent boys (15.3 ± 0.06 years of age; 63.0 ± 1.32 kg of weight, and 175.8 ± 0.78 cm of height). The boys were selected using cluster screening, i.e. the schools were randomly selected, and their 9th grade schoolboys were randomly invited to take part in the assessment. Initially, the data was collected from 112 boys, but 8 cases were withdrawn from the final analysis due to incomplete results and failure to wear the monitor throughout the defined period of time.

The physical activity of schoolboys was measured using actigraphs (*Tri-axis ActiTrainer Activity Monitors*). Boys were asked to wear the monitors for 7 consecutive days, i. e. whole week. The PA assessment monitors were placed on a special belt on the right hip site. The level of the intensity of physical activity was determined by calculating energy consumption in METs; bouts of physical activity (PA) had to last for at least 10 minutes without interruptions. Light PA (LPA) equals up to 3 METs, moderate PA (MPA) – 3–6 METs, and vigorous PA (VPA) – 8 or more METs. Based on the frequency of vigorous (VPA) and moderate physical activity (MPA) per week, the participants of this study were divided into physical activity groups.

The study was undertaken in spring 2010 during the second PE lesson on the measurement day in four randomly selected secondary schools of Kaunas. At first anthropometric measurements (standing height and weight) were performed. Then the Actigraphs were placed on the boys to register PA data for the whole week, i. e. from Monday 10 am to the next Monday 10 am. All of the participants and their parents or foster parents gave their informed consent to take part in the study. The time and location of the measurements to be taken were agreed upon in advance with the administration of the schools as well as the teachers. The volunteers were free to withdraw from the study at any time without any consequences.

Statistical analysis was carried out using SPSS 14.0 package for Windows. Standard statistical methods were used to calculate means and standard error (± SE). A one-way analysis of variance (ANOVA) was used to establish the differences between the measurements. A significance level of 0.05 was used.

RESEARCH RESULTS

The results of our study indicate that all participants experienced LPA on each of the assessed days. MPA on each day was experienced by 59.6% of the boys. No participants achieved VPA on a daily basis. A more detailed data on physical activity frequency are presented in Figure 1.

Moderate PA, which corresponds to 3–6 METs, is most often achieved 5–7 days/week (Figure 1). Only one case indicated MPA to be experienced less often than that. On the contrary, VPA was most often experienced by the boys on 1–3 days/ week; in separate cases – 4–6 days/week.

The total physical activity measured during the week was largely comprised by LPA, i. e. 79.8%; while MPA and VPA were 18.8 and 1.4%, respectively.

Based on the frequency of the experienced VPA during the week, the participants were divided into groups, and their weekly physical activity, with regards to the intensity, was analyzed (Figure 2).

In the groups of boys experiencing VPA on more than two days per week weekly LPA amount
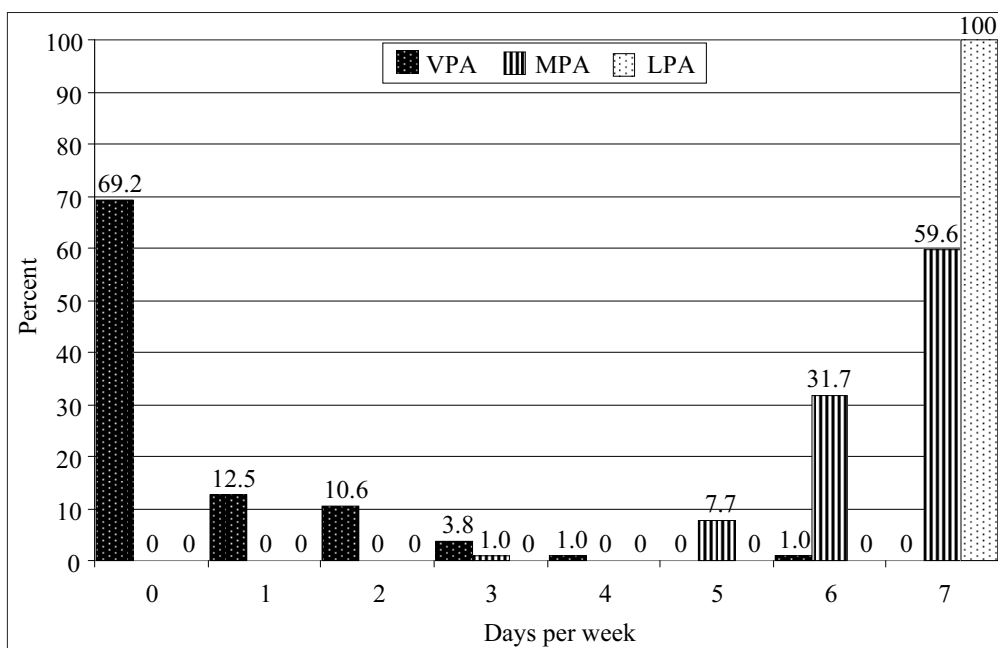
Figure 1. **The frequency of different intensity physical activity experienced by schoolboys**
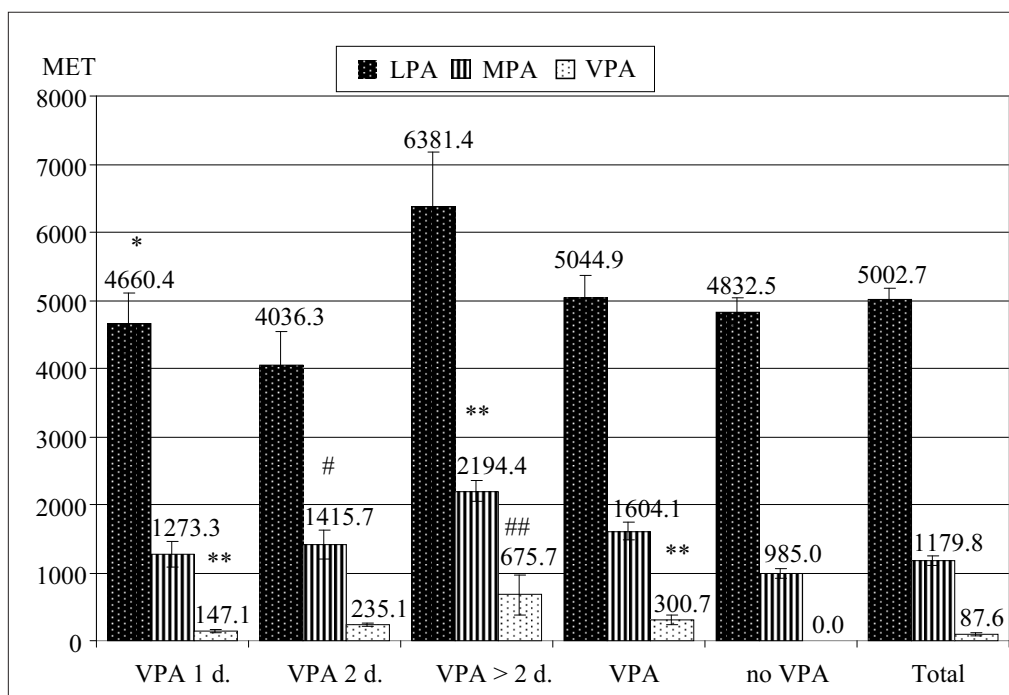
Figure 2. **The intensity-based weekly physical activity of the adolescent boys**

Note. The participants are divided into the groups according to the frequency of the experienced VPA during the week). * – p < 0.05 comparing with the groups of VPA experienced more than 2 days/ week; ** – p < 0.05 comparing with all of the groups except VPA 2 days/week; # – p < 0.05 comparing with a group having experienced no VPA group; ## – p < 0.05 comparing with all groups.

was greater than these who experience VPA only on 1 day/week (p < 0.05). Boys who achieved the level of VPA on two or more days per week had greater MPA amount than the boys who did not achieve the level of VPA during the week at all (p < 0.05). Furthermore, for boys who experience VPA more than two days per week, the total weekly VPA amount was significantly greater than for those boys who experienced VPA less often or not at all (p < 0.05).

After dividing the participants into groups according to the MPA frequency during the week, the weekly physical activity regarding the intensity was analyzed (Figure 3). There were no significant differences in weekly LPA amount.

The analysis of the intensity-based weekly physical activity indicated no significant differences in any of the PA levels. It was observed that the group of boys achieving MPA on less than 6 days/week was the one which did not experience VPA during the week.

The sum of the total amount of weekly PA, consisting of LPA, MPA and VPA, is presented in Figure 4.

Figure 3. **The intensity-based weekly physical activity of the adolescent boys (the participants are divided into the groups according to the frequency of the experienced MPA during the week)**
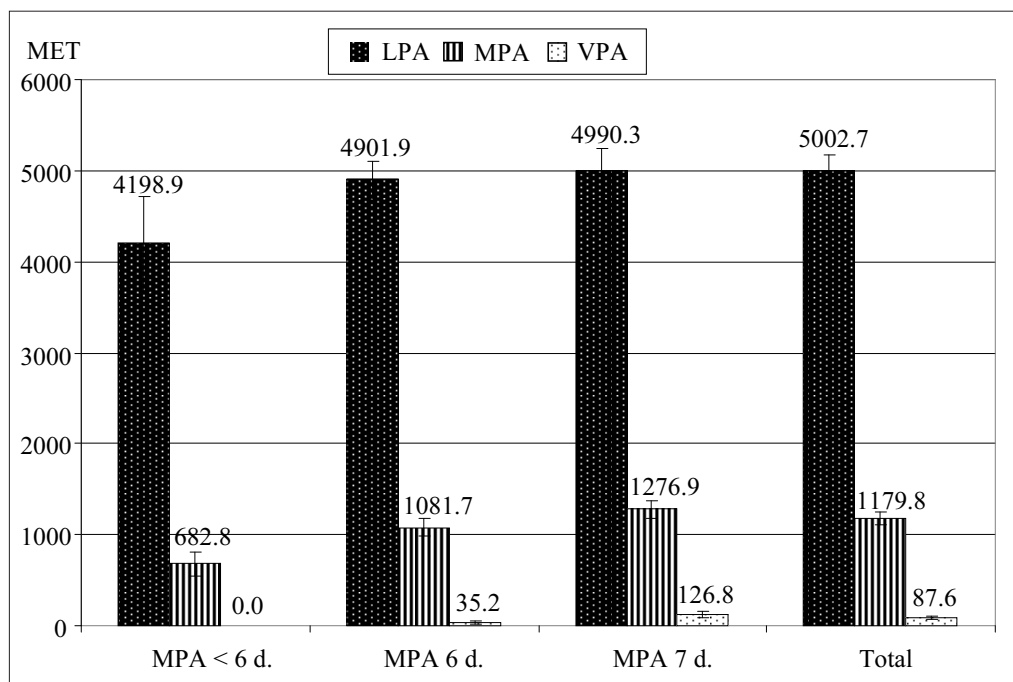
Figure 4. T**he total amount of weekly physical activity of the adolescent boys**
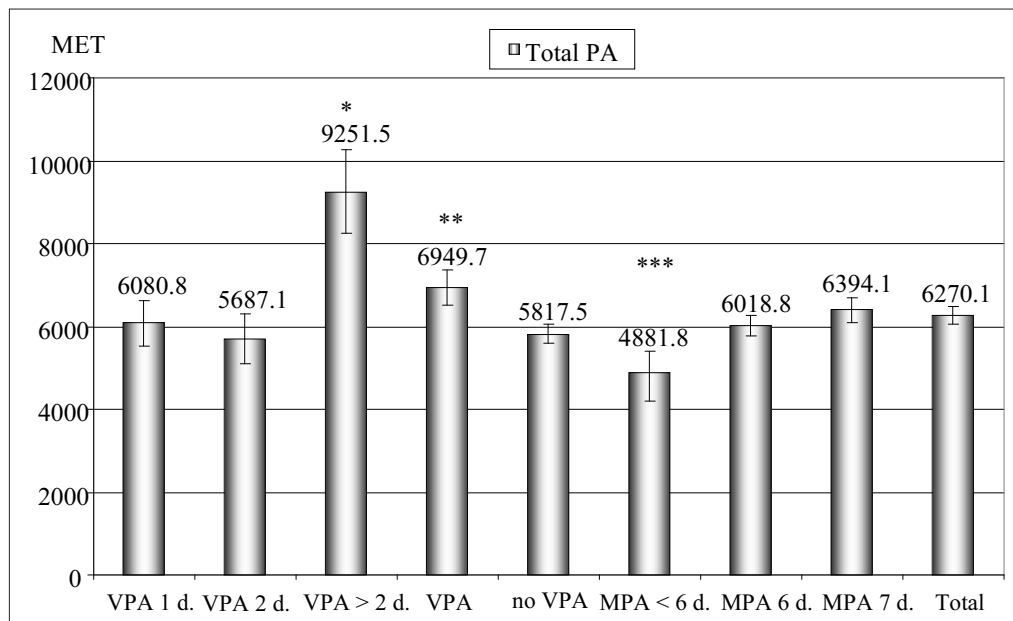
Note. * – p < 0.05 comparing with other groups; ** – p < 0.05 comparing with no VPA and MPA < 6 days/week; *** – p < 0.05 comparing with MPA 7 d/week.
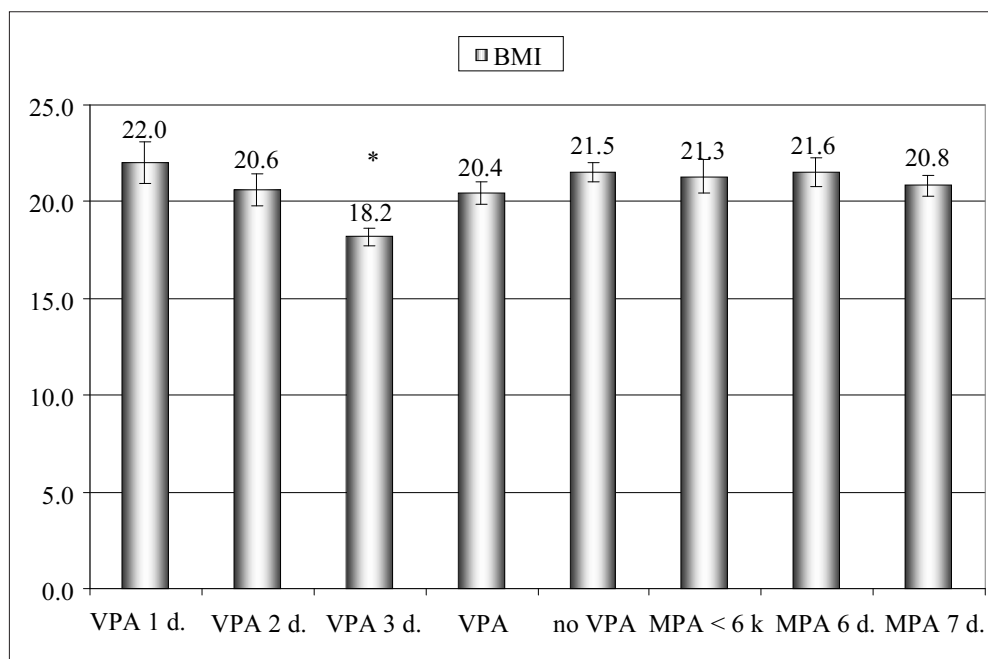
Figure 5. **The BMI of the boys of different weekly physical activity**

Note. * – p < 0.05 – comparing with "VPA 1 day/week". "no VPA". and "MPA 6 days/week".

Boys who experienced VPA more often than 2 days/week had a greater total amount of the weekly physical activity (p < 0.05) (Figure 4). For boys achieving VPA, physical activity amount was significantly greater than for those, who did not experience VPA or achieve MPA less than 6 days/week (p < 0.05). Boys whose MPA was less than 6 days/week had a significantly lower amount of weekly physical activity than those who achieved MPA for 7 days/week. The body mass index (BMI) of the boys of different weekly physical activity is presented in Figure 5.

These results indicate that boys experiencing VPA 3 or more days/week had significantly lower BMI than those who experienced VPA on 1 day/week, not experiencing VPA at all during the week, or than those who experienced MPA 6 days/week (p < 0.05).

The study revealed significant influence of the VPA experienced during the week for the total amount of PA; therefore, the duration of the VPA was also analyzed. The greatest duration of VPA was 69 minutes per day. On a singular occasion, one participant achieved VPA level 6 times per week, which amounted to 266 min, i. e. 1596 METs. Ten boys achieved VPA for more than 20 min/day. In all those groups, where boys achieved VPA, their mean VPA per day ranges from14 min 28 s to 19 min 47 s, although no significant differences between them were observed.

DISCUSSION

Evidence exists that regular physical activity improves children's physical, mental and social health (Louie et al., 2003). Continuous physical activity from an early childhood may improve metabolic function and regulate arterial blood pressure, which in turn may prevent from the chronic non-contagious diseases' risk factors (such as overweight, high blood pressure, hypercholesterolemia, etc.), and, therefore, may decrease the potential of occurrence of such chronic diseases as obesity or cardiovascular illnesses at an older age (Berenson, 2002), More physically active children have greater self-esteem (Kirkcaldy et al., 2002). Also, their academic achievements are greater (Wong, Louie, 2002).

The effect of PA on health depends on the amount of physical activity and is not adequate in all cases. The most legitimate PA recommendations for children and youth are recognized by the World Health Organization: moderate-to-vigorous PA (i. e. more than 3 METs) for at least 60 minutes each day. Research has shown that positive effects of more intensive PA to children's and adolescents' cardiovascular fitness are greater than that of a lower intensity, which is an important factor in the prevention of obesity (Ruiz et al., 2006). Our study indicated that adolescent boys who experience VPA and MPA more often during the week have

lower BMI ($p < 0.05$). Therefore, prescribing physical activity of a particular intensity should be one of the most important strategic elements in the enhancement of children's and adolescents' health and the prevention of diseases (Strong et al., 2005).

In 2002, a study attempted to compare physical activity of schoolchildren from 35 different countries: the means of physically active days per week were calculated using J. J. Prochaska et al. (2001) method. It was found that boys were physically active for 4.6 days per week, while girls – 3.9 days per week. The better results were observed in boys from Ireland, USA, and Great Britain; and in girls from Canada, Ireland, USA, Check Republic and Netherlands. If we attempt to evaluate physical activity based on this indicator, which reflects not only exercise and sport, but other types of physical activity as well, Lithuanian schoolboys' physical activity is rather promising, comparing with other countries.

In Lithuania, there is lack of studies that would be designed to objectively evaluate physical activity (using pedometers, accelerometers, etc.) in various populations, which would allow more precise and comprehensive analysis and comparison of the results with other studies.

CONCLUSIONS AND PERSPECTIVES

Boys who achieve VPA, have a greater total physical activity during the week than those boys who do not experience VPA. If boys achieve VPA on more than 2 days during the week, even if it is just for 10 min, there is a significant increase in the total amount of weekly physical activity as well as a decrease in their body mass index (BMI). If boys do not experience MPA at least for 6 days/week, the total amount of their weekly physical activity decreases. These preliminary results of objectively measured physical activity of adolescent boys revealed the proportions in weekly physical activity based on intensity and frequency; therefore, further research is necessary when analyzing the difference in schoolchildren's physical activity; and relationships with body composition and health-related physical fitness.

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OBJEKTYVIAI NUSTATYTO PAAUGLIŲ BERNIUKŲ SAVAITINIO FIZINIO AKTYVUMO REZULTATŲ ANALIZĖ

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Pasaulinėje mokslo praktikoje fizinio aktyvumo (FA) objektyvūs nustatymo metodai naudojami vis dažniau, tačiau Lietuvoje aptikti tokio pobūdžio tyrimų mums nepavyko. Taigi mes atlikome bandomąjį tyrimą objektyviai nustatydami paauglių FA ir norime pradėti plėtoti Lietuvoje tikslesnę FA nustatymo metodiką.

Tikslas – išanalizuoti objektyviai nustatyto paauglių berniukų savaitinio fizinio aktyvumo rezultatus.

Metodai. Mokinių FA nustatytas naudojant *Tri-axis ActiTrainer Activity Monitor* prietaisus. Berniukų buvo prašoma prietaisus nešioti savaitę kas minutę fiksuojant fizinę veiklą. Fizinio aktyvumo lygmuo buvo nustatomas taikant MET'ų skaičiavimo metodą, kai fizinė veikla trunka vienu metu ilgiau negu dešimt minučių. Analizuojant fizinio aktyvumo duomenis, FA standartizuotas pagal energijos suvartojimą, t. y. intensyvumo lygius. Pagal juos tiriamieji buvo suskirstyti į FA grupes pagal didelio ir vidutinio FA dažnį per savaitę.

Rezultatai. Tyrimo rezultatai parodė, kad visi tiriamieji patiria mažą FA kiekvieną dieną, vidutinį kasdien patiria 59,6% tiriamųjų. Tuo tarpu kasdien didelį FA patiriančių berniukų nenustatyta. Tiriamieji patiria vidutinį FA dažniausiai 5–7 dienas per savaitę, o didelį – nuo 1 iki 3 dienų per savaitę ir atskirais atvejais 4 ar 6 dienas per savaitę. Didžiąją dalį bendro FA sudaro mažo intensyvumo fizinė veikla – tai sudaro 79,8% nuo bendro per savaitę patirto FA, kai vidutinis FA sudaro 18,8%, didelis FA – 1,4%.

Aptarimas ir išvados. Didelį FA patiriančių berniukų bendras savaitinis FA didesnis, negu jo nepatiriančių berniukų. O patiriant didelį FA daugiau negu dvi dienas per savaitę bent po 10 minučių, reikšmingai padidėja bendro savaitinio FA apimtis, ir šie tiriamieji turėjo mažesnį KMI. Berniukams nepatiriant vidutinio FA bent šešias dienas per savaitę, sumažėja bendras savaitinis FA.

Raktažodžiai: FA dažnis, FA intensyvumas, FA apimtis.

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COMPARATIVE ANALYSIS OF LEARNING SPEED AND ACCURACY MOVEMENTS FOR HEALTHY PERSONS AND PERSONS WITH MULTIPLE SCLEROSIS

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ABSTRACT

Research background and hypothesis. Probability learning theory suggests that repeating the same movements many times we learn the way the movement is performed with some degree of probability. We suppose that persons with multiple sclerosis learn speed and accuracy movements slower than healthy persons.

Research aim was to establish and compare the learning peculiarities of speed and accuracy movements for healthy persons and persons with multiple sclerosis performing a task – five sets of 20 repetitions.

Research methods. The sample of the research included 12 healthy persons and 10 persons with multiple sclerosis. The study was conducted using Dynamic Parameter Analyzer DPA-1 for arm and leg movements.

Research results showed that multiple sclerosis had a significant effect ($p < 0.05$) on the average speed of movement (Va), maximal speed of movement (Vm), time to maximal speed (TVm), and time to target (Tv).

Discussion and conclusions. Learning effect occurred in the course of the whole task, and it was the same for both persons with multiple sclerosis and healthy persons. Research results showed that learning dynamics was almost the same for persons with multiple sclerosis and healthy persons, but the indices of MS persons were worse, i. e. they performed movements slower and with greater variability compared to healthy persons.

Keywords: reaction time, manual task, complexity of the task, movement learning.

INTRODUCTION

In healthy myelin, our movements are not impaired, they are fast and accurate. When the layer of myelin is damaged, the spread of nervous impulse is distorted or broken. Scars occur in the place of distorted myelin, and this is called sclerosis (Zheng et al., 2003).

Multiple sclerosis is a demyelinising disease of the central nervous system which damages the brain and the spinal cord. It is a chronic demyelinising disease. The real causes of this disease are not known (Malcienė, 2004). Pathogenesis of this disease is not exactly known, either. This disease is thought to be autoimmune (Halpern et al., 2011). MS is a hardly predictable disease. Its symptoms as well as the disease itself are absolutely individual. The symptoms depend on the place in the central nervous system which is affected by the disease.

A motor skill is the ability to plan and implement the aim of the movement – a task (Skurvydas, 2008). There are three stages of movement skill development – cognitive, associative and automation. During those stages certain functional and structural changes occur in some areas of the cerebral cortex, basal ganglion, and cerebellum (Karni et al., 1998).

Research hypothesis: learning speed and accuracy movements of persons with multiple sclerosis is slower than that of healthy persons.

Research aim was to establish and compare the learning peculiarities of speed and accuracy movements for healthy persons and persons with multiple sclerosis performing a task – five sets of 20 repetitions.

RESEARCH METHODS

The research was carried out following the principles of the Declaration of Helsinki about the ethics of experimentation with humans. The study was conducted in the LAPE Laboratory of Human Motoric using Dynamic Parameter Analyzer DPA-1 for arm and leg movements.

The sample of the research included 22 subjects. Ten of them were with multiple sclerosis they and made up a research group regardless of the form of the disease. Persons with multiple sclerosis (MS) had been ill with this disease for 13.8 ± 11.3 years. Their age was 42 ± 10.5 years, height 173.1 ± 7.7 cm, and weight 74.1 ± 15.5 kg. The control group consisted of 12 healthy persons aged 44.3 ± 1.4 years, height 167.2 ± 4 cm, and weight 79.1 ± 4.2 kg. The patients volunteered to participate in the research after they were acquainted with the research aims, procedures and the course.

DPA-1 is a device which allows researching reaction time, dynamic (strength, power) and kinematic (range of movement, speed, acceleration) characteristics of movements.

During the research the subjects sat in a special chair at the table with DPA-1 fastened on it. The back of the subject was straight, resting on the chair back, both arms were flexed at the elbow joint at the angle of 90^0 so that the upper arms were at the sides of the body and the forearms were leaning of the support panel. The position of DPA-1 chair was regulated so that the subject could sit comfortably in a standard position. The distance between the computer screen and the eyes was ~0.7 m.

The subjects performed the task with their right hand. According to the task prepared beforehand, the target (a red circle 0.007 m in width) appeared on the screen at the determined time. The distance between the start zone and the target was 0.16 m. The path of arm movement was identically repeated on the computer screen. During each task the subject set the handle symbol, 0.0035 m wide, at the start zone on the computer screen (the center of a green circle 0.01 m wide). The programme generated an audible signal every1-3 seconds, and at the same time the subject had to react and to push the handle so that he/she could hit the target. The cycle of measurement ended when the handle symbol hit the target. Information about the task performed was stored on the computer and later moved to *Microsoft Excel* programme.

The complicated task was performed. The subject had to react to a target appearing on a computer screen and push the handle so that the symbol circle reached the target and stopped in it as fast as possible and in the most exact movement trajectory. The target appeared on the computer screen in the same place all the time. The end moment of movement was recorded when the center of the handle symbol stopped in the circle and remained in it no shorter than 0.03 s. After the task was explained the subjects were allowed three trials, the results of which were not recorded. Then the subjects performed five sets of tasks with 20 repetitions in each. The rest interval between the sets of repetitions was 2 min, and the repetitions of one set were performed without stopping, and we registered the maximal and the average speed of movement, reaction time and the path of movement for the right hand. After each repetition the subjects saw their result on the computer screen. They were encouraged to perform the task as fast and as accurately as possible.

The data analysis was performed using SPSS 17.0 programme package. The data were processed calculating the mean values of the researched indices ($\overline{x}$), mean standard deviation (s), coefficient of variance (VA%), Pearson's correlation coefficient (r). The significance of results of different factors was assessed using two-factor analysis of variance. The significance of difference was set at $p < 0.05$.

RESEARCH RESULTS

The analysis of the research results showed that comparing MS persons and healthy persons statistically significant differences were found in the following registered indices: time to target (Figure 1), average speed (Figure 2), maximal speed (Figure 3), and time to maximal speed (Figure 4).

Research results showed that disease had a significant effect on the average speed of movement ($p < 0.05$), maximal speed of movement ($p < 0.05$), time to maximal speed ($p < 0.05$), and time to target ($p < 0.05$).

Research results indicated that learning dynamics of MS patients and healthy persons was almost the same, but the indices of MS patients were worse, i. e. they performed everything slower than healthy persons. The interaction between the groups (MS patients and healthy persons) and repeated trials was statistically significant, i. e. learning dynamics of the average speed of movement ($p < 0.05$), maximal speed of movement ($p < 0.05$), time to maximal speed ($p < 0.05$), and time to target ($p < 0.05$) was different. Learning

Figure 1. **Mean values of time to target (s) for MS persons and healthy persons performing the task – five sets with 20 repetitions in each set**
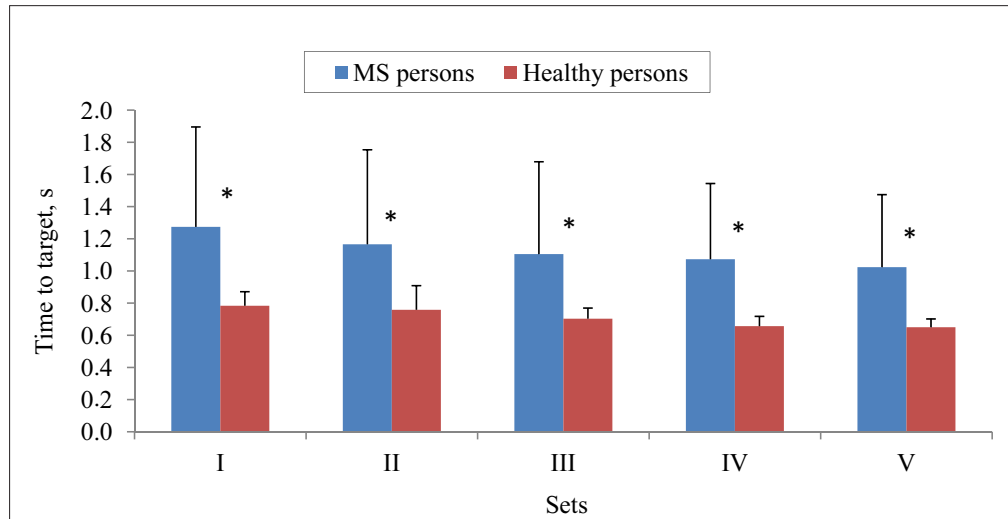
Note. * – p < 0.05, comparing MS persons with healthy persons.

Figure 2. **Mean values of average speed (mm/s) for MS persons and healthy persons performing the task – five sets with 20 repetitions in each set**
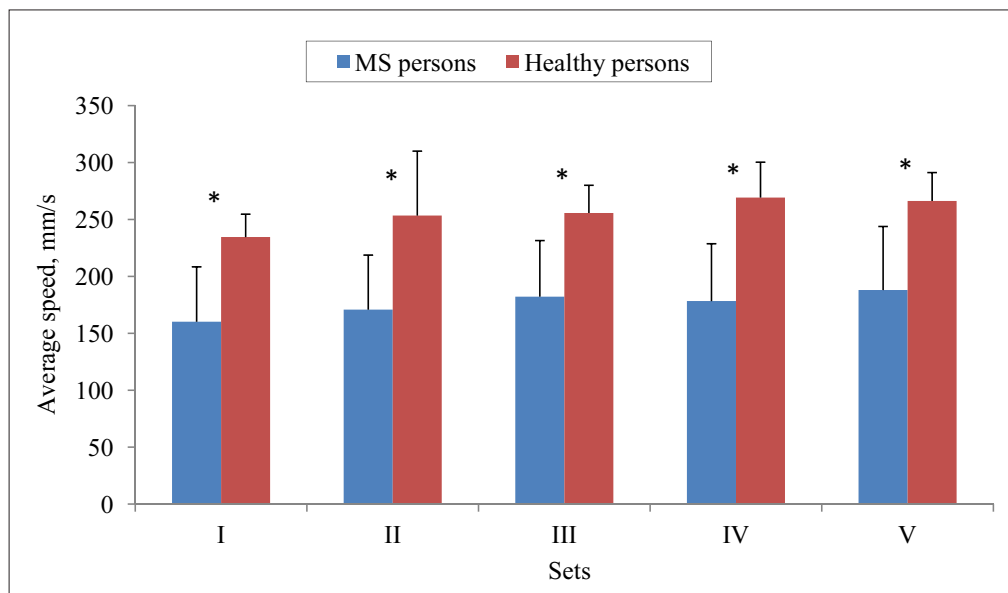
Note. * – p < 0.05, comparing MS persons with healthy persons.

Figure 3. **Mean values of maximal speed (mm/s) for MS persons and healthy persons performing the task – five sets with 20 repetitions in each set**
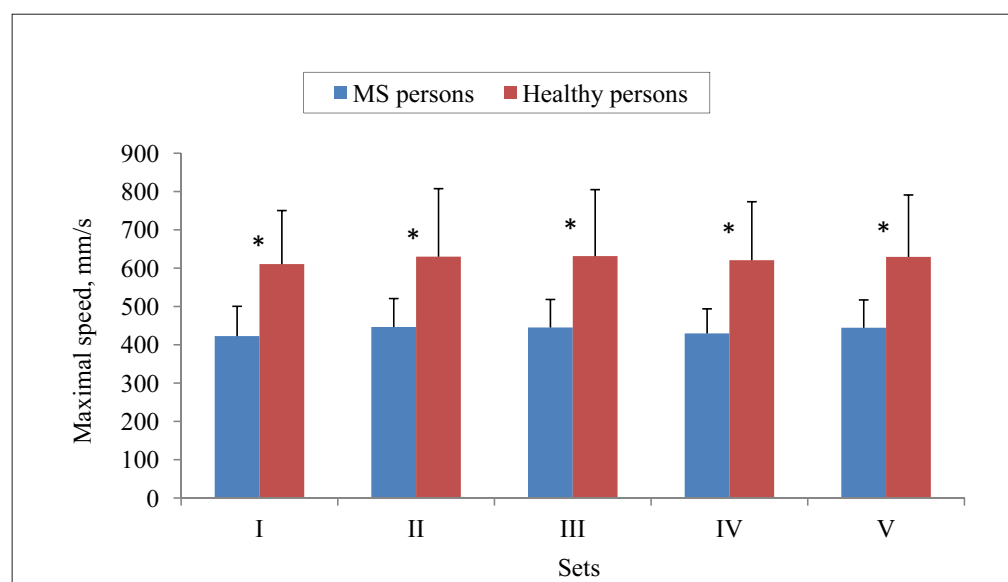
Note. * – p < 0.05, comparing MS persons with healthy persons.
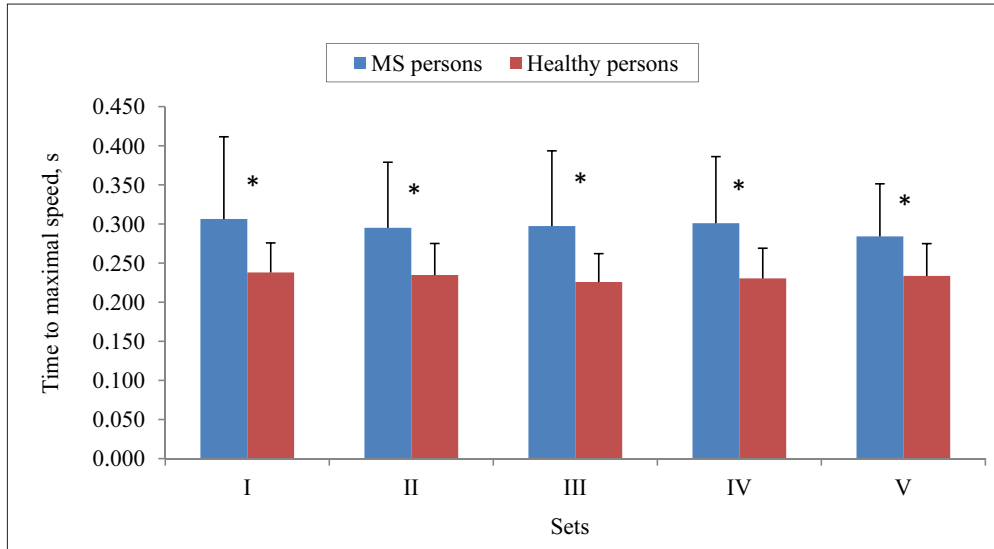
Figure 4. **Mean values of time to maximal speed (s) for MS persons and healthy persons performing the task – five sets with 20 repetitions in each set**

Note. * – p < 0.05, comparing MS persons with healthy persons.

Indices	Reaction time, %		Time to target, %		Average speed, %		Maximal speed, %		Time to maximal speed, %		Path of movement	
Sets	MS	H	MS	H	MS	H	MS	H	MS	H	MS	H
1	24.8	9.1	44.9	11.1	30.6	8.5	18.9	22.8	33.7	15.8	7.2	7.9
2	27.5	9.9	49.6	19.7	28.2	22.3	16.6	28.1	27.8	17.1	13.1	6.6
3	27.5	7.8	43.9	9.4	27.3	9.5	16.1	27.4	31.3	16.1	10.4	5.3
4	20.2	9.1	42.1	9.2	31.6	11.5	22.4	24.6	28.3	16.7	18.6	5.1
5	20.6	7.8	40.6	7.9	29.6	9.3	17.1	25.6	22.7	17.6	7.1	3.5

Table. **Coefficients of variance of the registered indices for MS persons and healthy persons**

Note. MS – MS persons, H – healthy persons.

effect was observed during the whole task, and it was the same to both MS patients and healthy persons.

Aiming at evaluating the dispersion of our researched indices we calculated the coefficients of variance of indices in different tasks. The research showed that MS persons performed the tasks with greater variability compared to healthy persons. The highest coefficients of variance for MS persons were observed in the indices of time to target (40.6–49.6%) and time to maximal speed (22.7–33.7%). The highest coefficients of variance for healthy persons were observed in the indices of maximal speed (22.8–28.1%).

DISCUSSION

As far as we know, this is the first research analyzing speed and accuracy movement learning for patients with multiple sclerosis.

The aim of this study was to establish differences in learning speed and accuracy movements for persons with multiple sclerosis and healthy persons. The main conclusion obtained

was that persons with multiple sclerosis performed movements slower and with greater variability, though their accuracy did not differ from that of healthy persons.

Movement learning depends on two different processes – fast and slow learning. Fast learning process is characterized by fast learning and fast forgetting. Slow learning process is characterized by slow learning and slow forgetting (Ethier et al., 2008). In speed and accuracy tasks, children's accuracy improves at the expense of their speed, but for adults only the average speed of movement increases (Motiejūnaitė et al., 2011). In this research the results in both groups improved, and the accuracy did not decrease in either group.

Researchers claim that it is difficult to reconcile the speed and accuracy of movements because when the movement is performed fast, its duration decreases, thus the possibilities of its correction decrease as well (Schmidt, Lee, 1999). D. Mickevičienė et al. (2008) suggest that the more complicated the task, the slower the reaction and the maximal speed of movement, compared to a simple task. But it does not mean that the speed of

movement would be greater while reacting faster to a simple stimulus. All those findings confirm Hick's law stating that reaction time is directly proportional to the complexity of movement (complexity of the task).

Researchers suggest that there is no significant difference between reaction time results when performing the task with the right and the left hand. There is also no significant difference between genders. Though there is no significant difference if the task is performed by a woman or a man, but research results show that women's reaction time is slower than that of men. Both women and men reach faster and more accurately when performing a task with their right hand, but as their left hand is concerned, their reaction is rather more accurate than faster (Motiejūnaitė et al., 2010). A. Zuoza et al. (2009) studied the performance of speed and accuracy movements with the left hand, contrary to this research. Their findings show that the left hand is less accurate than the right hand, but the target is reached rather fast. The left hand can develop greater strength and power comparing it with the right hand.

One of the most interesting studies was carried out by A. Skurvydas et al. (2009) where they studied the dependence of movement speed on the body mass. The main conclusion obtained by the authors was that the greater the body mass, the slower the reaction time.

Dispersion of variance is considered low when the coefficient of variance is from 0 to 10%, average – from 10 to 20%, and high – more than 20% (Gonestas, Strielčiūnas, 2003). Our results showed that MS patients performed speed and accuracy movements with high variability, but the accuracy of movement did not suffer from that and it did not differ from that of healthy persons. Movement variability is the greatest in the first

stage and the least in the automation stage. It was observed that moving to the second stage (associative or perception) movement variability could increase (Liu et al., 2006). In our research movement variability steadily declined in both groups.

Research results showed that comparing the coefficients of variance of the registered indices for MS patients and healthy persons we could claim that dispersion of variance of all indices for MS patients was greater compared to healthy adult persons.

Summing up, we suggest that for both healthy and MS persons, movement accuracy improved at the expense of speed, the average of the mean speed improved, and the time to target became shorter. The majority of the registered indices significantly changed for both groups of subjects. We suppose that in the process of fast learning MS persons tend to alter the variables of their movements more than healthy persons. We suggest that feedback and the mechanism of the correction of mistakes as internal models of fast learning alter more among MS persons that healthy persons.

CONCLUSIONS AND PERSPECTIVES

1. Persons with multiple sclerosis performed speed and accuracy movements slower and with greater variability, though their accuracy did not differ from that of healthy persons.

2. The duration of planning movement of persons with multiple sclerosis, which is indicated by reaction time, was significantly longer than that of healthy persons.

3. Dynamics of movement learning did not differ for persons with multiple sclerosis and healthy persons.

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SVEIKŲ IR SERGANČIŲJŲ IŠSĖTINE SKLEROZE GREITŲ BEI TIKSLIŲ JUDESIŲ MOKYMOSI LYGINAMOJI ANALIZĖ

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Anot tikimybinės išmokimo teorijos, daug kartų kartojant tuos pačius judesius galima greičiau ir tiksliau juos atlikti. Manoma, kad sergančiųjų išsėtine skleroze (IS) greitų ir tikslių judesių mokymasis yra lėtesnis nei sveikų asmenų.

Tikslas – nustatyti bei palyginti sveikų asmenų ir sergančiųjų IS greitų bei tikslių judesių mokymosi ypatumus atliekant užduotį – 5 serijas po 20 kartojimų.

Metodai. Tiriamąją grupę sudarė 12 sveikų asmenų ir 10 sergančiųjų IS. Tyrimas atliktas naudojant žmogaus rankų ir kojų judesių dinaminių parametrų analizatorių DPA-1.

Rezultatai. Sergančiųjų IS vidutinio judesio greičio (Va), maksimaliojo judesio greičio (Vm), laiko iki maksimaliojo greičio (TVm) ir laiko iki taikinio (Tv) rodikliai buvo prastesni nei sveikų tiriamųjų ir reikšmingai skyrėsi (p < 0,05).

Aptarimas ir išvados. Mokymosi efektas buvo pastebimas visos užduoties metu ir pasireiškė vienodai tiek tarp sergančiųjų IS, tiek tarp sveikų tiriamųjų. Tyrimo rezultatai parodė, kad sergančiųjų IS ir sveikų asmenų mokymosi kaita yra beveik tokia pati, tačiau sergančiųjų rodikliai yra prastesni, t. y. jie viską atlieka lėčiau ir kaičiau nei sveiki asmenys.

Raktažodžiai: reakcijos laikas, užduotis rankoms, užduoties sudėtingumas, judesių mokymasis.

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ALTERNATION OF PHYSICAL AND FUNCTIONAL POWERS OF HIGH PERFORMANCE FEMALE BMX CYCLIST DURING YEARLY TRAINING CYCLE

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ABSTRACT

Research background and hypothesis. There is a lack of information on BMX cyclists' training. Information about athletes' of this cycling event training and their organism adaptation to physical loads practically does not exist in Lithuania. Consequently, it is relevant to reveal the main characteristics of alternation of Lithuanian high performance international class female cyclists' physical and functional powers. The hypothesis that physical and functional power indices between BMX cyclist and track cyclist differ is being tested.

Research aim was to reveal characteristics of Lithuanian high performance female BMX cyclist's physical and functional power indices and their alteration during yearly training cycle; to compare them to analogical data of other cycling event athletes.

Research methods. Research of a Lithuanian BMX female cyclist (A) was organized in VPU Sport Science Institute in 2010–2011. Research was carried out during these yearly cycle periods: preparatory (I), competition (II), and transitional (III).

Research results. Physical development indices were established and muscular power in various energy producing zones was analyzed. Maximal anaerobic alactate glycolytic capacity (MAAGC) with applied 30-s test was established as well. Functional capacity of blood circulation and respiratory system was evaluated under resting heart rate, its rate alteration after standard physical load, and after one minute recovery; under these data Roufier index was calculated. Indices of female BMX cyclist's physical and functional powers were compared to analogical results of female sprint track cyclist – 200 m event World champion (B), and female track cyclist – 3 km pursuit event World championship bronze winner (C).

Discussion and conclusions. Our analyzed BMX cyclist's SMCP is very high and exceeds the same index of cyclists in other various specializations analyzed. However, AAMP and mixed anaerobic alactate glycolytic muscular power indices are insignificantly lower than analogical indices of one of the best World track sprinters. Elite cyclist's (C), whose part of energy, during competition period, is produced in aerobic way, functional capacity of blood circulation system is the highest and these indices of the investigated BMX cyclist are lower than aerobic capacity of cyclist C.

Keywords: bicycle motocross, physical development, muscular power, functional capacity.

INTRODUCTION

Bicycle motocross (BMX) event in cycling sport is rather recent; International Olympic Committee included it into the list of Olympic sports in 2003, and in 2008 this event was on cycling events program of Beijing Olympic Games. BMX track is ragged 380–400 m length route with up-hills, slopes, sharp-turns, springboards, and straight distances (Politi, Heazlewood, 1996). The best World's BMX female cyclists ride this distance in 40–45 s; thus specific abilities are needed in such format competitions (Campillo et al., 2007; Herman et al., 2009). J. Cowell et al. (2011) indicate high muscular power in short-term work to be essential for athletes of this cycling event, which is only lower than analogical power of 200 m sprint event track cyclists. Anaerobic-glycolytic energy producing way is also highly significant because of its considerable input to energetics during such

short-term work (Hodgins et al., 2001; Herman et al., 2009). For such reason training of BMX female cyclists has to be purposefully directed to developing characteristics specifically needed for this sport (Bertucci, Hourde, 2001; Mateo et al., 2011).

High performance female bicycle motocross athlete, who successfully participates in most international competitions, has been recently trained in Lithuania. Road and track cyclists' training and main characteristics of their body adaptation to physical loads do not lack researchers' attention in foreign as well as in Lithuanian scientific publications (Mujika, Padilla, 2001; Atkinson et al., 2003; Faria et al., 2005; Tubelis et al., 2007, 2009; Dadelienė et al., 2008; Buividas, Milašius, 2011), but yet there is a shortage of information on BMX cyclists' training. Information about athletes of this cycling event training and their body adaptation to physical loads practically does not exist in Lithuania. Consequently, it is relevant to reveal the main characteristics of Lithuanian high performance international class female cyclist's physical and functional powers alternation during yearly cycle, which would further lead to the improvement of female cyclists' training process for this event.

Research aim was to reveal characteristics of Lithuanian high performance female BMX cyclist's physical and functional power indices and their alteration during yearly training cycle; to compare them to analogical data of other athletes in cycling events.

RESEARCH METHODS

Research of Lithuanian BMX female cyclist (A) was organized in VPU Sport Science Institute in 2010–2011. Research was carried out during these yearly cycle periods: preparatory (I), competition (II), and transitional (III). Physical development indices of body mass, muscle and fat mass and their correlation (MFMI), body mass index (Norton et al., 1996), and the power of both hands was established. Muscular power in various energy producing zones was analyzed as well. Efficiency of alactate anaerobic energy producing mechanisms was measured after establishing single muscular contraction power (SMCP) (Bosco et al., 1982) with ergometer step test and alactate anaerobic muscular power (AAMP) (Margaria et al., 1966) with 10-s test on veloergometer. Maximal anaerobic alactic glycolytic capacity (MAAGC) with applied 30-s test on veloergometer (*Wingate test*) (Bar-Or, 1987) and blood lactate (La) concentration were also established. Functional capacity of blood circulation and respiratory system was evaluated under resting heart rate (HR), its rate alteration after standard physical load, and after one minute recovery; under these data Roufier index was calculated. Methods of this research have been described by J. Skernevičius et al. (2004).

Indices of female BMX cyclist's physical and functional powers were compared to analogical results of female sprint track cyclist – 200 m event World champion (B), and female track cyclist – 3 km pursuit event World championship bronze winner (C).

RESEARCH RESULTS

Our investigated athlete's body mass, muscle and fat mass were the highest during preparatory stage (Table 1). During competition stage athlete's body mass, muscle and fat mass diminished and during transitional stage they were even lower. Athlete's SMCP and AAMP had the highest values during competition period: they were respectively 32.2 and 16.8 W/kg (Table 2). When analyzing BMX cyclist's specific working efficiency indices alteration during yearly cycle, it can be indicated that absolute as well as relative maximal instantaneous, anaerobic alactate muscular power in 10-s work test and anaerobic alactate glycolytic power in 30-s work test were the highest during competition period testing (Table 3). Lactate concentration after 30-s physical load test, which absolute average power reached 732 W, on maximal exertion was up to 16.2 mmol/l. Although functional capacity indices of blood circulation system fluctuated a little during yearly cycle, the requirements for athlete's aerobic capacity were fully answered. During yearly cycle the heart rate of the investigated athlete fluctuated from 40 to 48 b/min, Roufier index – from 2.0 to 0.8 (Table 4).

DISCUSSION

When analyzing physical development data (Figure 1), it is apparent that female BMX cyclist is considerably heavier than track sprinter (B) and pursuit athlete (C). M. Slyter et al. (2001) indicate optimal female BMX cyclists' body mass to be 70–74 kg. Our analyzed female BMX cyclist's body mass fluctuated between 75 and 78 kg during yearly cycle. Cyclist's muscle and fat mass is higher than

Table 1. **Alternation of female BMX cyclist's physical development and muscle-fat mass correlation indices during yearly training cycle**

No.	Periods	Body mass, kg	BMI, kg/m²	Hands power, kg		Muscle mass, kg	Fat mass, kg	Muscle fat mass index
				Right	Left			
1	Preparatory	78.0	28.0	42	40	43.2	10.5	4.09
2	Competition	76.5	26.3	45	40	40.3	9.5	4.24
3	Transitional	75.5	26.4	46	42	40.3	8.2	4.91

Table 2. **Alternation of female BMX cyclist single muscular contraction power (SMCP) and anaerobic alactate muscular power (AAMP) indices during yearly training cycle**

No.	Periods	SMCP		AAMP	
		W	W/kg	W	W/kg
1	Preparatory	2309	30.6	1200	15.7
2	Competition	2460	32.2	1266	16.8
3	Transitional	2176	28.8	1125	14.9

Table 3. **Alternation of female BMX cyclist's physical powers during yearly training cycle**

No.	Periods	Power W						La, mmol/l
		10 s				30 s		
		max	W/kg	av.	W/kg	av.	W/kg	
1	Preparatory	1470	19.3	1030	13.6	705	9.3	14.4
2	Competition	1614	21.2	1059	13.9	732	9.6	16.2
3	Transitional	1426	19.0	1032	13.8	669	8.3	13.7

Table 4. **Alternation of female BMX cyclist's functional capacity of blood circulation system indices during yearly training cycle**

No.	Periods	Roufier index	HR at rest, b/min	HR after load, b/min	
				Straight after	after 60 s
1	Preparatory	0.8	40	100	68
2	Competition	2.0	44	104	72
3	Transitional	1.6	48	104	64

of other researched cyclists. BMX cyclist's muscle mass was 43.2 kg during preparatory stage and we assume that this led her to developing higher SMCP than that of contestants' of other cycling events. Other authors (Tubelis et al., 2007, 2009; Dadelienė et al., 2008; Mateo et al., 2011) also state that muscle mass of cyclists, where in the anaerobic alactate or mixed anaerobic alactate glycolytic reactions dominate competition period, correlate with SMCP, AAMP, and MAAGC. Reduction of BMX cyclist's body mass and fat mass indices during transitional stage can be related to reduction of specific strength exercises during training sessions.

SMCP of the investigated female BMX cyclist increased from 25.5 to 32.2 W/kg since testing in 2008 (Dadelienė et al., 2008) and exceeded SMCP of sprint and pursuit athletes, whose indices were

respectively 27.4 and 28.7 W/kg. The highest AAMP was in sprint cyclist (B) – 18,0 W/kg, though, and it was identical – 16.8 W/kg – in BMX cyclist and pursuit cyclist (Figure 2). T. Hodgkins et al. (2001) suggest that success in sprint cycling and BMX cross-country racing depends on muscle quality to develop high power during short-term work.

Maximal and average anaerobic alactate muscular power on 10-s veloergometer test is the highest in athlete B and reaches respectively 23.8 and 15.0 W/kg, and in BMX cyclist it is marginally lower and reaches respectively 21.2 and 13.9 W/kg (Figure 3).

Being of high athletic fitness level, all three athletes represented sufficiently high anaerobic alactate muscular power. Index of 30-s work power on maximal exertion test was 9.6 W/kg in female

BMX cyclist and in track cyclist it was 10.3 W/kg and so in pursuit athlete it was even higher and reached 11.0 W/kg. Similar anaerobic alactate power indices were estimated by Bertucci and Ch. Hourde (2011), who researched France national BMX team female cyclists' physical powers. They estimated that when performing anaerobic alactic glycolytic power test (*Wingate*) French cyclists reached average 10.6 W/kg power, which was higher by 28% than regional cyclists' level, as it was established by W. Bertucci et al. in 2007.

Blood circulation system representing indices of our investigated cyclists A and B, whose competition period is short, were of sufficient level. However, Roufier index of cyclist C, who trains for pursuit event, was even higher (–1.2). Research results have reveaedl that cyclists' A and B functional capacity of blood circulation system is high despite the fact that in preparatory period considerable part of the load is performed in training zones of anaerobic alactate and glycolytic energy producing muscles. Functional indices of blood circulation system of cyclist C, where considerable part of energy is produced in aerobic reactions in competition period, were particularly high and corresponded to the level of World elite athletes (Lucia et al., 2002).
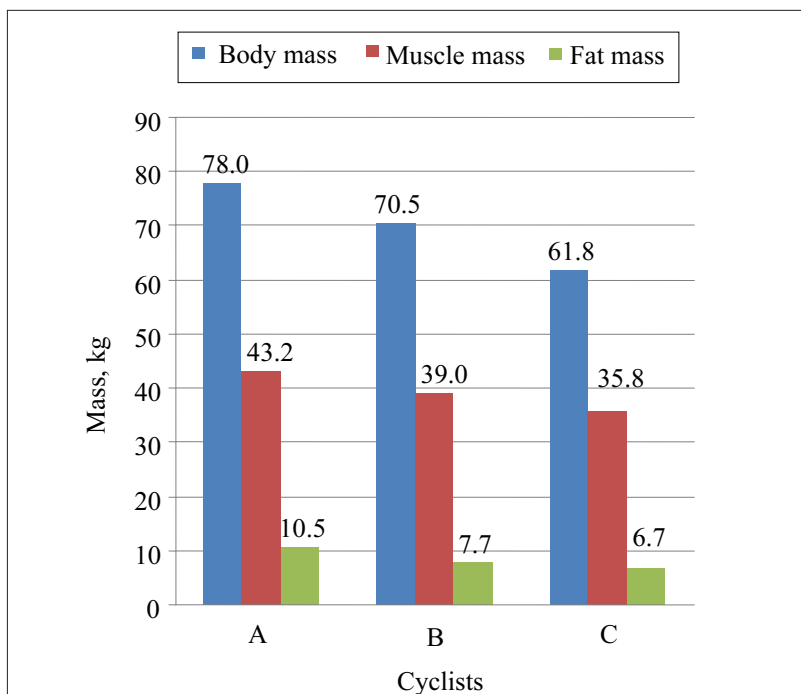
Figure 1. **Comparative characteristics of different specialization female cyclists' physical development indices**
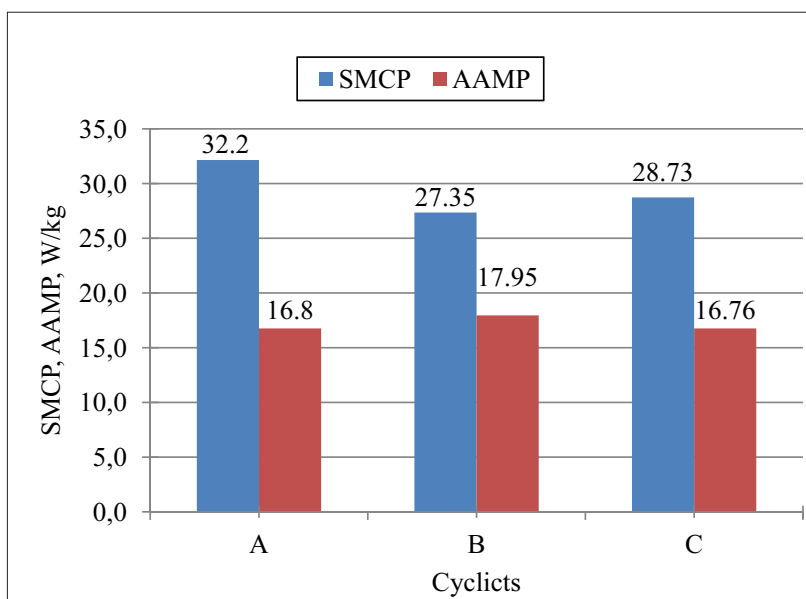
Figure 2. **Comparative characteristics of different specialization female cyclists' SMCP and AAMP indices**

Figure 3. **Comparative characteristics of different specialization female cyclists' indices of relative muscular power at various energy producing zones**
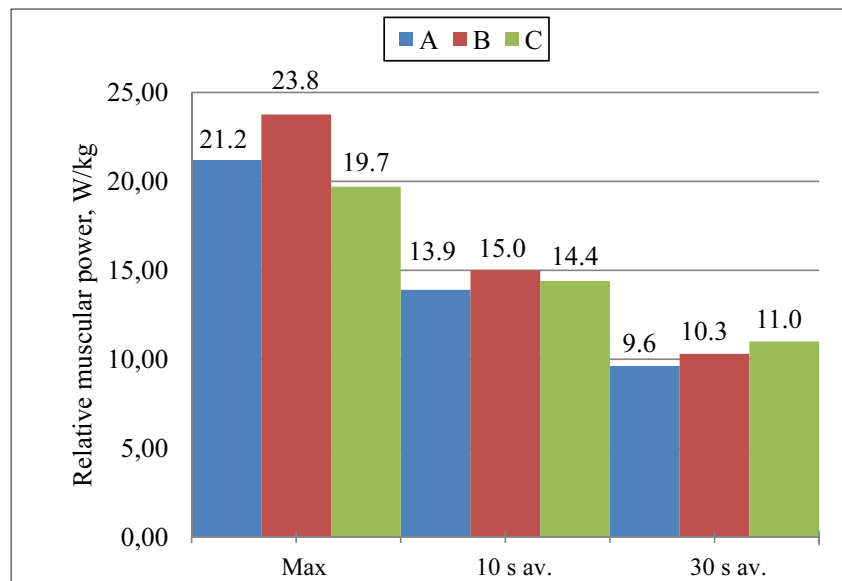
CONCLUSIONS AND PERSPECTIVES

1. Female BMX cyclist's body mass, muscle and fat mass fluctuated in descending order from preparedness to competition period during yearly cycle. This athlete weighed more than cyclists of track sprint and pursuit.

2. Our investigated BMX cyclist's SMCP is very high and exceeds the same index of other cyclists in various specialization analyzed, however, AAMP and mixed anaerobic alactate glycolytic muscular power indices are insignificantly lower than analogical indices of one of the best World track sprinters and glycolytic capacity is lower than that track of track sprinter and pursuit cyclist.

3. Functional capacity of blood circulation system of elite cyclist (C), whose part of energy during competition period is produced in aerobic way, is the highest and these indices of our investigated BMX cyclist are slightly lower than aerobic capacity of cyclist C.

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DIDELIO MEISTRIŠKUMO BMX DVIRATININKĖS FIZINIŲ IR FUNKCINIŲ GALIŲ KAITA METINIU TRENIRUOČIŲ CIKLU

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Apie BMX dviratininkų rengimą informacijos dar nepakanka. Lietuvoje šios dviračių rungties sportininkų rengimo, jų organizmo adaptacijos prie fizinių krūvių klausimais duomenų beveik nėra. Todėl svarbu nustatyti tarptautinės klasės BMX dviratininkės fizinių ir funkcinių galių svarbiausius bruožus. Tyrimu tikrinama hipotezė, kad BMX dviratininkių parengtumo rodikliai skiriasi nuo treko dviratininkių.

Tikslas – atskleisti Lietuvos didelio meistriškumo BMX dviratininkės fizinių galių ir funkcinių rodiklių ypatumus bei kaitą metiniu treniruotės ciklu ir palyginti juos su kitų rungčių dviratininkių analogiškais duomenimis.

Metodai. 2010–2011 metais buvo organizuotas Lietuvos BMX dviratininkės (A) tyrimas. Tyrimai atlikti parengiamuoju (I), varžybų (II) ir pereinamuoju (III) metinio ciklo laikotarpiais. Nustatyti fizinio išsivystymo rodikliai. Tirtas raumenų galingumas įvairiose energijos gamybos zonose. Nustatytas maksimalusis ir anaerobinis alaktatinis-glikolitinis pajėgumas (MAAGP) atliekant 30 s trukmės testą. Kraujotakos ir kvėpavimo sistemos funkcinis pajėgumas vertintas pagal ramybės pulsą, jo dažnį po standartinio fizinio krūvio, po vienos minutės atsigavimo ir iš šių duomenų paskaičiuotą Rufjė indeksą.

Rezultatai. BMX dviratininkės fizinių ir funkcinių galių rodikliai palyginti su treko dviratininkės sprinterės 200 m rungties pasaulio čempionės (B), treko dviratininkės ir 3 km persekiojimo pasaulio čempionato bronzos medalio laimėtojos (C) analogiškais rezultatais.

Aptarimas ir išvados. Mažųjų dviračių kroso tiriamosios VRSG yra labai didelis ir pralenkia šį kitų specializacijų dviratininkių rodiklį, tačiau AARG, mišraus anaerobinio alaktatinio-glikolitinio raumenų galingumo rodikliai nedaug nusileidžia vienos iš pajėgiausių pasaulio treko sprinterės analogiškiems rodikliams. Elito dviratininkės (C), kurios varžybinės veiklos metu dalis energijos pagaminama aerobiniu būdu, kraujotakos sistemos funkcinis pajėgumas yra didžiausias, o BMX dviratininkės šie rodikliai mažai nusileidžia jos aerobiniam pajėgumui.

Raktažodžiai: mažųjų dviračių krosas, fizinis išsivystymas, raumenų galingumas, funkcinis pajėgumas.

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CARDIOVASCULAR ADJUSTMENTS DURING GRADED EXERCISE STRESS

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ABSTRACT

Research background and hypothesis. Cardiac function provides an adequate blood supply to all organs thus changes in the performance and functional state of cardiac muscles during exercising are very important.

Research aim. The aim of the study was to find out the peculiarities in adjustment of cardiovascular system in dependence on the type of adaptation to physical loads during graded stress.

Research methods. The study participants, 17 non-athletes, 23 endurance, 19 sprint and 21 combat sport athletes, underwent a bicycle ergometry of incremental increase in provocative workload (graded stress). A 12-lead ECG was reordered and a computerized program allowed to measure ECG parameter, the ratio of JT/RR intervals and the velocity of adaptation of cardiovascular system to exercising (V_{Ad}), by calculating the difference between the relative changes of JT interval and RR interval as a difference: $V_{Ad.} = (JT_i/JT_0)\ 100\% - (RR_i/RR_0)\ 100\%$.

Research results. No significant functional ischemia was found in endurance cohort during the graded stress while it was expressed in non-athletes' cohort and slightly smaller in sprint and combat cohorts. Maximal values of other ECG or ABP parameters registered during graded stress did not reveal significant differences between cohorts.

Discussion and conclusions. Functional ischemia is an important factor limiting muscular and cardiac performance during the graded exercise stress. The exercise type plays a significant role in developing the velocity of adaptation of cardiovascular system at onset of exercising. Faster adaptation at onset of exercise is more characteristic of sprint and combat sports than representatives of endurance or non-athletes.

Keywords: cardiovascular system, adaptation, functional ischemia.

INTRODUCTION

Exercise training is associated with adaptations of cardiovascular system (Noakes, 2000; Dickhuth et al., 2004; Duncker, Bache, 2008) and these long-term adaptations are important background in acute response at onset of exercising (Noakes et al., 2001; Calbet et al., 2009). There are many studies designed for the analysis of central and peripheral mechanisms limiting exercise performance. The classical theory (Mitchell, Blomqvist, 1971) explains that exercise is limited after oxygen delivery to the exercising muscles becomes inadequate (Bassett, Howley, 2000; McKay et al., 2009). Cardiac function has to provide an adequate blood supply to all organs, including the skeletal muscles at rest and during exercise, thus the changes in performance and functional state of cardiac muscles during exercising are very important.

Reactivity of the cardiovascular system to acute exercise stress is also an important feature concerning the body abilities during exercising. The fast mobilization of body functions at onset of exercise is very important in many kinds of sport and there are a lot of situations in competitive sport when this ability is a determinant factor or important element of functional capabilities (Платонов, 2004; Ezerskis et al., 2009). The objective of this study was to find out the peculiarities in adjustment of

cardiovascular system in dependence on the type of adaptation to physical loads during graded stress.

RESEARCH METHODS

The study participants were 17 voluntary students who were not engaged in the sport training (aged 20.9 ±1.21, body mass index 22.3 ± 0.38); well-trained athletes (all participant were members of various national teams), i. e. 23 athletes in the endurance group; 19 – sprint group and 21 – combat-sport group (box, judo and wrestling).

The subject underwent a bicycle ergometry of incremental increase in provocative workload (graded stress), i. e. a 50 W increase in workload every 60 seconds (60 revolutions/min) and they exercised to the inability to continue workload or to a predetermined goal (submaximal heart rate) unless distressing cardiovascular symptoms supervened.

Arterial blood pressure (ABP) was measured using Korotkoff method and a computerized ECG analysis system "Kaunas–Workload", developed at the Kaunas University of Medicine, Institute of Cardiology, was employed for 12-lead ECG recording and analysis. The changes in RR interval or heart rate (HR), JT interval, ST-segment depression and in the ratio of intervals JT/RR were analyzed. A computerized program allowed evaluating the velocity of adaptation of cardiovascular system to exercise, i. e. the index of velocity of adaptation (V_{Ad}), by calculation the difference between the relative changes of JT interval and RR interval as a difference: $V_{Ad.} = (JT_i/JT_0) 100\% - (RR_i/RR_0) 100\%$.

Statistical analysis. All the data were expressed as mean ± standard error of the mean (SEM). Hypothesis concerning the difference between means was verified using Student t test for independent and dependent variables. Difference in means was regarded as statistically significant when error probability with respect to criteria was $p < 0.05$.

RESEARCH RESULTS

The results obtained during the bicycle ergometry of incremental increase in provocative workload showed that the greatest ability to perform the incremental workload was in the endurance group. All participants of the experiment, representatives of endurance group, underwent a 250 W workload and 60 percent of them – even 350 W. The least working capacity was demonstrated by the participants – representatives of non-athlete group. They were able to reach the workload of 200–250 W. No significant differences ($p > 0.05$) were found between sprint and combat sport groups. The participants of these cohorts underwent the workload of 250–300 W.

Table presents the values of cardiovascular indices registered during the bicycle ergometry. No statistically significant differences were found in heart rate, arterial blood pressure, JT interval and JT/RR values between the groups ($p > 0.05$) at the end of workout of incremental increase the workload.

Table. **Values of cardiovascular indices registered before and at the end of the workload during graded stress (bicycle ergometry)**

Cohort	HR, b/min.	ST-segment depression, mV	JT interval, ms	JT/RR	ABP, mmHg
Non-athletes	78.3 ± 2.5 178.2 ± 4.7	0.07 ± 0.01 0.62 ± 0.05	268.2 ± 3.2 163.1 ± 4.6	0.358 ± 0.01 0.631 ± 0.03	$123.2 / 75.6$ $198.2 / 31.6$
Endurance	66.4 ± 2.3 172.4 ± 1.8	0.05 ± 0.01 0.26 ± 0.07	294.3 ± 3.3 161.2 ± 1.2	0.343 ± 0.01 0.621 ± 0.02	$121.6 / 78.1$ $193.7 / 35.0$
Sprint	79.4 ± 2.6 178.2 ± 2.9	0.08 ± 0.01 0.42 ± 0.06	266.5 ± 3.1 165.2 ± 3.4	0.353 ± 0.01 0.633 ± 0.02	$120.5 / 80.2$ $189.4 / 36.6$
Combat sport	72.7 ± 2.5 178.4 ± 2.8	0.10 ± 0.01 0.41 ± 0.06	265.7 ± 4.0 162.9 ± 2.3	0.351 ± 0.01 0.628 ± 0.03	$122.6 / 75.8$ $203.1 / 34.5$

Note. Upper row – before; lower row – maximal values, i. e. at the end of workout; in column of ABP of systolic and diastolic values are presented.

The results obtained during the study showed that the velocity of adaptation (V_{Ad}) at onset of exercise depended on the residual effects of training. The fastest adaptation at onset of exercise was in sprint group ($16.3 \pm 1.33\%$). The values of velocity of adaptation in endurance group were $19.8 \pm 1.34\%$. The difference between sprint and endurance cohorts was statistically significant ($p < 0.05$). The velocity of adaptation in cohort of non-athletes were the slowest – $21.4 \pm 1.33\%$. To sum up, the faster adaptation at onset of exercise is quite in character for sprint and combat cohorts than endurance or non-athletes cohorts.

The differences between the cohorts were expressed in values of ST-segment depression at the end of workout, in values of changes of cardiovascular indices at the same grades of the task, in relative changes of cardiovascular indices with the performance, i. e. developed power on bicycle ergometer. Figure presents the values of ST-segment depression registered before the workload and the maximal registered values during exercising. As these figures represent the sum of negative amplitudes of ST-segment depression in 12-leads of ECG, the results obtained by the analysis of this parameter are as follows. No significant functional ischemia was found in endurance cohort during the graded stress (0.26 ± 0.07 mV). Only four participants from endurance cohort showed highest ST-segment depression values, but for others there no significant changes were found in this parameter. The highest values of ST-segment depression were registered in non-athlete cohort (0.62 ± 0.05 mV) and slightly smaller

in sprint and combat cohorts (0.42 ± 0.06 mV and 0.41 ± 0.06 mV, respectively).

DISCUSSION

Maximal exercise tests are related to motivation and it is important to take into account the fact that some participants finished the exercising before maximal mobilization of cardiovascular system. In our previous study (Poderys et al., 2005) we showed that the change in the ratio of JR/RR intervals of ECG allowed assessing the dynamics of mobilization of cardiovascular system during the exercise tests or workouts. The studies designed to assess the individual peculiarities of body functioning during the workloads usually have a task to evaluate to what extent the body function was mobilised during the performance of the task. Absolute values such as the heart rate during exercising can be used for these purposes. Such methods are practical but not precise for outlining to what extent the mobilisation of cardiovascular system occurred (Vainoras, 1996, 2002; Poderys, 2000). A special study performed by V. G. Boshkov (Бочков, 1986) showed that activation of physiological systems could be expressed by normalised values in the ratio of underlying indices of the physiological system. These underlying indices of cardiac function can be the ratio of JT and RR intervals (Vainoras, 1996) The JT interval is not independent of the ventricular depolarisation pattern and can be used as an accurate means of following the duration of ventricular depolarisation (Banker et al., 1997) and its changes interrelate with the changes in

Figure. **ST-segment depression registered before and during the graded stress**
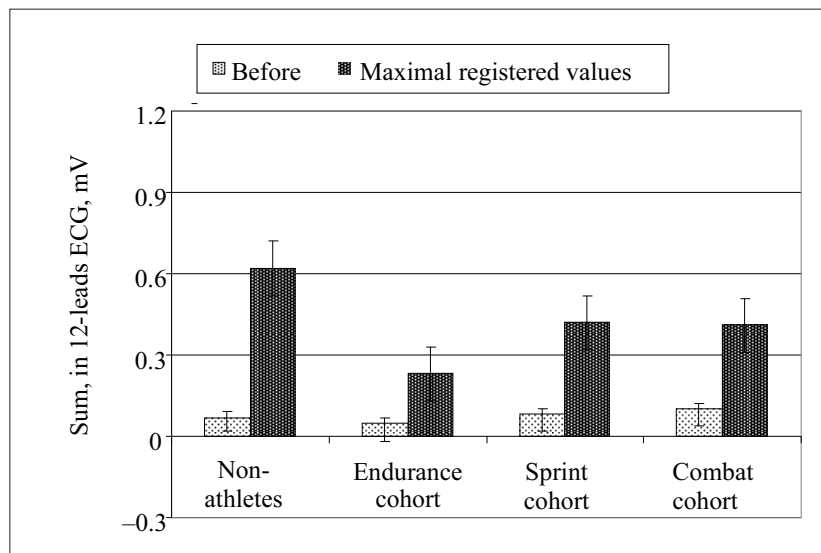
Note. Values of ST-segment depression is a sum of negative amplitudes in 12-leads.

the intensity of metabolism (Vainoras, 1996). The results obtained during this study have shown that the ratio JT/RR can be useful for outlining to what extent a cardiovascular function was mobilised. As it was found in our study, the ratio in JT/RR varied very much alike as it was established by V. G. Boshkow (Бочков, 1986). According to V. G. Boshkow, these biological constants can be expressed mathematically (1/e = 0.368 and 1 –1/e = 0.632). During this study we found that in all groups this ratio was more than 1.62. This value of JT/RR evidenced that the participants of the study performed the workload up to inability to continue it and a full mobilization of functional abilities of the cardiovascular system was achieved .

Individual peculiarities and differences between various cohorts can be assessed making use of the index of velocity of adaptation (V_{Ad}), which represents the difference between the relative changes of RR and JT intervals of ECG. Our previous studies (Poderys et al., 2002; Poderys 2000, 2005) showed that the velocity of adaptation at onset of exercise depended more on the functional state or residual effects of training than on the type of exercise-test. During the study designed to evaluate the changes in the velocity of adaptation in sprint cohort significant changes under the influence of concentrated heavy training loads were found, i. e. 16.3 ± 1.33% before training, 26.2 ± 1.42% – after 2-week of heavy training, and 20.1 ± 1.35% – after one week of recovery (Poderys, 2002). All this allows us to conclude that individual peculiarities and differences between cohorts in the velocity of adaptation of the cardiovascular system at onset of exercise can be evaluated making use of the difference between the relative changes of RR and JT intervals of ECG. The results obtained in this study have shown what a significant role in developing and improving the velocity of adaptation of cardiovascular system at onset of exercise is played by the exercise type or the type of adaptation. The main differences in the content of training between the sprint and endurance cohorts are found in the prevailing interval methods of training in sprint cohort and sustained exercise in endurance events (Платонов, 2004; Ezerskis et al., 2009). Sudden change in the intensity in workloads during the fight is typical of combat events. Thus, these changes could be a possible explanation of differences in the values of the velocity of adaptation between the endurance, sprint or combat cohorts during this study.

Prognostic importance of ischemic episodes detected by ST-segment monitoring with continuous 12–lead ECG during exercise test was emphasized in many investigations (Jernberg, 1999; Yazigi et al., 1998 Vainoras, 2002; Stern, 2002). The fact that myocardial hypoxia causes a progressive cardiac failure was shown by A. V. Hill even at the beginning of XIX century (Hil et al., 1924). When the oxygen supply becomes inadequate it is probable that the heart rapidly diminishes its output avoiding exhaustion in this way. The classical theory (Mitchell, Blomqvist, 1971) proposes that exercise is limited only after oxygen delivery to the exercising skeletal muscles becomes inadequate, inducing anaerobiosis (Bassett, Howley, 1997, 2000). The central governor theory predicts that cardiac output will fall during hypoxia in proportion to the reduction in oxygen delivery to the heart, specifically to prevent hypoxic damage to the heart or other vital organs including, perhaps, the brain and respiratory muscles (Noakes et al., 2001). Our finding that the cohorts showed the highest physical working capacity and the smallest changes of ST-segment depression, and other studies mentioned above the importance of mechanisms related with stress-induced ischemia in the diagnosis of performance abilities.

CONCLUSIONS AND PERSPECTIVES

1. No significant functional ischemia was found in endurance cohort during the graded stress while it was expressed in non-athlete cohort and slightly in sprint and combat cohorts. Maximal values of other ECG or ABP parameters registered during graded stress did not reveal significant differences between cohorts.

2. The exercise type plays a significant role on developing and improving the velocity of adaptation of cardiovascular system at onset of exercising. Faster adaptation at onset of exercise is more characteristic of sprint and combat sports than representatives of endurance sport or non-athletes.

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ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS GREITOJI ADAPTACIJA PAKOPOMIS DIDINAMO KRŪVIO METU

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Pagrindinė širdies ir kraujagyslių sistemos funkcija yra tiekti organams deguonį ir energines medžiagas, todėl pačios širdies funkcinės būsenos vertinimas yra svarbus.

Tikslas – nustatyti, kaip organizmas adaptuojasi prie pakopomis didinamo fizinio krūvio ir kaip tas krūvis veikia širdies ir kraujagyslių sistemos funkcinų rodiklių kaitos ypatybes.

Metodika. Nesportuojantys asmenys (n = 17) bei greitumo (n = 23), ištvermės (n = 19) ir dvikovos sportininkai (n = 21) atliko pakopomis didinamą fizinį krūvį veloergometru iki negalėjimo tęsti krūvį. Buvo matuojamas arterinis kraujospūdis (AKS) ir registruojama 12-kos standartinių derivacijų elektrokardiograma (EKG). Vertinta ŠSD, RR ir JT intervalų trukmės ir jų santykis (JT/RR), ST-segmento depresija ir adaptacijos greičio rodiklis: $V_{Ad.} = (JT_i/JT_0) \, 100\% - (RR_i/RR_0) \, 100\%$.

Rezultatai. Didėjant atliekamam krūviui, ištvermės sportininkų funkciniai išeminiai reiškiniai nebuvo išreikšti, tačiau tai buvo labai ryšku nesportuojančiųjų grupėje ir kiek mažiau – greitumo ir dvikovos sportininkų grupėse. Nebuvo aptikta reikšmingo skirtumo tarp grupių lyginant krūvio metu užregistruotas didžiausias kitų EKG ir AKS rodiklių reikšmes.

Aptarimas ir išvados. Reikšmingas veiksnys, turintis įtakos raumenų ir širdies darbingumui pakopomis didinamo krūvio metu, yra didėjantys funkciniai išeminiai reiškiniai miokarde. Širdies ir kraujagyslių sistemos adaptacijos prie krūvio greitis reikšmingai susijęs su adaptacijos pobūdžiu. Didžiausias adaptacijos greitis nustatytas tarp sprinto bėgikų ir dvikovininkų, mažesnis – tarp ištvermės sportininkų ir nesportuojančių asmenų.

Raktažodžiai: širdies ir kraujagyslių sistema, adaptacija, funkcinė išemija.

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MEASURING THE COMPLEXITY OF A PHYSIOLOGICAL TIME SERIES: A REVIEW

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ABSTRACT

Research background and hypothesis. Complex Systems Theory indeed is a solid basis for a scientific approach in the analysis of living, learning, and evolving systems. A number of different entropy estimators have been applied to physiological time series attempting to quantify its complexity.

Research aim. The aim of the paper is to review most popular complexity estimators (entropies) applied in biological, medical, sport and exercise sciences and their performances.

Research results. Various measures of complexity were developed by scientists to compare time series and distinguish regular (e. g. periodic), chaotic, and random behavior. In this paper a brief review of most popular complexity estimators – Sample Entropy, Control Entropy, Spectral Entropy, Wavelet Entropy, Singular-Value Decomposition Entropy, Permutation Entropy, Base-Scale Entropy, Entropy based on Lempel-Ziv algorithm – and their performances is presented. In biological applications they are used to distinguish peculiarities in behavior of biological systems or may serve as non-invasive, objective means of determining physiological changes under steady or non-steady state conditions.

Discussion and conclusions. The choice of a particular entropy estimator is determined by the goal type, the capability of estimators in characterizing the constraints on a physiological time series, its robustness to noise considering the above-mentioned advantages and disadvantages of particular algorithms. It is difficult to apply analytical solutions in the analysis of behavior of living, learning, and evolving systems and new approaches and solutions remain on the agenda.

Keywords: physiological time series, complexity, entropy.

INTRODUCTION

Complex Systems Theory indeed is a solid basis for a scientific approach in the analysis of living, learning, and evolving systems. A great number of details in the sequence of movements, a variety of situations which the player is required to face, a wide range of techniques and skills which the handling of those situations encoupan_consist the complexity which is required to understand in sport science. A hallmark of physiologic systems is their extraordinary complexity. This complexity arises from the interaction of a myriad of structural units and regulatory feedback loops that operate over a wide range of temporal and spatial scales, enabling the organism to adapt to the stresses of everyday life. The nonstationarity and nonlinearity of signals generated by living organisms defy traditional mechanistic approaches based on homeostasis and conventional biostatistical methodologies. Recognition that physiologic time series contain ''hidden information'' has fueled growing interest in applying concepts and techniques from the

complexity theory, including fractal analysis and nonlinear dynamics, to a wide range of biomedical problems from molecular to whole body levels (Mayer, 2001; Goldberger et al., 2002). The use of non-linear methods for estimating variability in a given class of phenomena is very important to access the underlying nature of these processes. On the one hand, the variability in a time-series might entail relevant information on the underlying dynamics of the phenomenon, and, on the other hand, changes in the variability might inform us about deviations experienced by a system (Goldberger et al., 2002; Seely, Macklem, 2004). Once introduced, the family of statistics has been widely applied to a variety of physiological and clinical datasets such as genetic sequences, hormone pulsatility, respiratory patterns, heart rate variability, electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), datasets of gait analysis and postural control and other important physiological experimental time series and has shown its superiority to most complexity measures (Chena et al., 2009). Various measures of complexity were developed to compare time series and distinguish regular (e. g. periodic), chaotic, and random behavior. In this paper a brief review of most popular complexity estimators (entropies) applied in biological, medical, sport and exercise sciences and their performances are presented.

TECHNIQUES REVIEW

The main types of complexity parameters are:
- Information theory estimates of complexity (entropies);
- Fractal dimensions;
- Chaos-based estimates of complexity (Lyapunov exponents, etc.).

They are all defined for typical orbits of presumably ergodic dynamical systems, and there are profound relations between these quantities (Bandt, Pompe, 2002). At the heart of such analysis, is the concept of quantifying the information evolution of transitions associated with probabilities assigned to each state, with a goal of providing single value (an entropy) to describe this information content (Bollt, Skufca, 2009). With an appropriate finite partition of labeled states,

$i = 1, 2, ..., n$, and a probability measure p_i on that partition, the well known Shannon entropy of a random variable is defined by:

$$SE = -\sum p_i \cdot ln\, p_i \qquad (1)$$

The discrete distribution (which may be conditional on another variable) of values has high entropy if it is uniform and corresponds to an unpredictable variable, and low if the distribution is sharply peaked and the variable can be predicted. Other entropies are Tsallis entropy, Escort-Tsallis entropy, Renyi entropy (Rosso et al., 2006; Rosso et al., 2010). In this paper only the definition of statistical complexity measure in terms of just "disorder" or "information" is considered, leaving out the approach when the amount of complexity C is obtained by computing the product between the entropy H, and a sort of distance to the equipartition state in the system named as the disequilibrium D (Rosso et al., 2010):

$$C = H \cdot D = -K \sum_{i=1}^{R} p_i \cdot ln\, p_i \cdot \sum_{i=1}^{R} \left(p_i - \frac{1}{R}\right)^2, \qquad (2)$$

where H and D are, respectively, the entropy and the disequilibrium, p_i represents the probability associated to the state i; R is the number of states, and K is a positive normalization constant.

The most popular entropy measures for complexity estimation of the physiological time series are:
- Approximate entropy – ApEn (Sample Entropy – SampEn);
- Control Entropy – CE;
- Spectral Entropy – SE;
- Wavelet Entropy – WE;
- Singular-Value Decomposition Entropy – SVDEn;
- Permutation Entropy – PE;
- Base-Scale Entropy;
- Lempel-Ziv algorithm.

Sample Entropy (SampEn). Sample Entropy provides a characterization of time series complexity in terms of their regularity. SampEn (m, r, N) is precisely the negative natural logarithm of the conditional probability that a dataset of length N, having repeated itself within a tolerance r for m points, will also repeat itself for $m + 1$ points, without allowing self-matches (Richmann, Moorman, 2000):

$$SampEn(m,r,N) = -ln[A^m(r)/B^m(r)] , \quad (3)$$

where

$$B^m(r) = (N-m)^{-1} \sum_{i=1}^{N-m} B_i^m(r), \quad (4)$$

$$A^m(r) = (N-m)^{-1} \sum_{i=1}^{N-m} A_i^m(r), \quad (5)$$

$B^m(r)$ is the number of vectors $\boldsymbol{x}_m(j)$ within r of $\boldsymbol{x}_m(i)$, where j ranges from 1 to $N-m$ $(j \neq i)$, $A^m(r)$ is the number of vectors $\boldsymbol{x}_{m+1}(j)$ within r of $\boldsymbol{x}_{m+1}(i)$, where j ranges from 1 to $N-m$ $(j \neq i)$. Sample Entropy is a useful tool for investigating the dynamics of heart rate and other time series, when the assumption of the stationarity of time series is fulfilled. One of the main advantages of the SampEn analysis is that it can be applied to both deterministic and stochastic systems (see (Ramdani et al., 2009) for more details).

Control Entropy (CE). The Control Entropy is closely related to the technique of SampEn, but is defined in terms of the first difference of the signal, via correlation sums (Bollt, Skufca, 2009; McGregor et al., 2009). The effect of short time correlation is removed by using a Theiler window. Given a scalar data set $\{z_i\}_{i=1}^N$ from an ergodic process, the Control Entropy is defined as

$$CE(\{z_i\}; m,r,T) = ln \frac{C_2(\{z_i\},m,r,T)}{C_2(\{z_i\},m+1,r,T)} , \quad (6)$$

where C_2 is the correlation sum

$$C_2(\{z_i\}; m,r,T) =$$

$$= \frac{1}{N_{pairs}} \sum_{i=m}^{N} \sum_{j>i+T} \Theta(r - \|\boldsymbol{v}_i - \boldsymbol{v}_j\|), \quad (7)$$

$$\boldsymbol{v}_i = (z_i, z_{i-1}, \cdots, z_{i-m+1}), \quad (8)$$

where Θ is the Heaviside function, m is the embedding dimension, r is a parameter defining a neighborhood, and N_{pairs} is the total number of pairs of delay vectors $\boldsymbol{v}$, integer parameter $T \geq 1$ is a Theiler window used to mitigate effects of time correlation in the data. The control entropy should be calculated in a moving window along the time series and is a tool that is not subject to conditions of stationarity and is generally applicable to any measurement signal, but, in particular, it is well suited to monitoring streaming continuous signal that is recorded at high frequencies (Bollt, Skufca, 2009). This is in contrast to other commonly used regularity statistics that are typically applied to discretized samples, e.g., stride rate, *R-R* interval of heart rate, etc. This characteristic could allow researchers to exploit the more robust information properties of streamed waveforms which may provide a novel insight into the regularity of physiological parameters (McGregor et al., 2009). It is found (McGregor et al., 2009) that symbolization of time series adds a great deal of stability but still has sufficient robustness and rapid convergence relative to continuous *r*-neighborhood statistic.

Spectral Entropy (SE). The SE (**Inouye et al., 1991**) is the Shannon entropy formula suitably normalized and applied to the power spectral density of the signal:

$$SE = -\sum p_k \cdot \ln p_k / \ln N, \quad (9)$$

where p_k are the normalized spectral amplitudes of frequency bin *k, N* – number of frequencies and $\sum p_k = 1$. The SE is a measure of how concentrated or widespread the Fourier power spectrum of a signal is – the SE can take values from zero (if the spectrum contains purely a single oscillatory peak) to one (if the spectrum is that of uncorrelated white noise – i. e. $p_k = 1/N$). SE quite often is the easiest compute if the data sets are large. However, the applicability of this method to short lasting and nonstationary data segments has restrictions – the Fourier transform (FT) requires stationarity of the signal. The disadvantages of the spectral entropy defined from the FT can be partially resolved by using a short time Fourier transform (Rosso et al., 2001). Another drawback of SE is insufficient sensitivity. To overcome these limitations a time evolving entropy can be defined from a time-frequency representation of the signal as provided by the wavelet transform.

Wavelet Entropy (WE). Wavelet analysis is a method which relies on the introduction of an appropriate basis and a characterization of the signal by the distribution of amplitude in his basis. Wavelet analysis is a suitable tool for detecting and characterizing specific phenomena in time and frequency planes (see (Rosso et al., 2001; Rosso et al., 2006) for more details). The WE is defined as (Rosso et al., 2001; Rosso et al., 2006)

$$WE = -\sum p_j \cdot \ln p_j / \ln N, \quad (10)$$

$$p_j = E_j/E_{tot} , \quad (11)$$

$$E_j = \sum_k |C_j(k)|^2, \tag{12}$$

$$E_{tot} = \sum_j \sum_k |C_j(k)|^2, \tag{13}$$

where $C_j(k)$ are the discrete wavelet transform coefficients at octave j and time k. The WE carries information about the degree of order/disorder associated with a multi-frequency signal response and on the other part can provide additional information about the underlying dynamical process associated with the signal. In contrast to SE, WE are capable of detecting changes in a nonstationary signal due to the localization characteristics of the wavelet transform.

Singular-Value Decomposition Entropy (SVDEn). Given a time series $\{x_i\}_{i=1}^L$ the phase points can be reconstructed by time delay embedding (Kantz, Schreiber, 2003):

$$\{\vec{x}_i\}_{i=1}^{L-(d-1)\tau}, \tag{14}$$

where $\vec{x}_i = [x_i, x_{i+\tau}, x_{i+2\tau}, \cdots, x_{i+(d-1)\tau}]^T, \tag{15}$

L – length of time series; τ– time delay; d– the embedding dimension; $(\cdot)^T$ denotes the transpose of a real matrix. Taking the standard singular value decomposition on the covariance matrix of reconstructed phase space matrix:

$$R = U\Lambda V^T, \tag{16}$$

the SVDEn is computed via the equation (Sabatini, 2000):

$$SVDEn = -\sum \lambda_k \cdot \ln \lambda_k / \ln K, \tag{17}$$

where λ_k – normalized k-th eigenvalue; K– number of eigenvalues.

In essence, similar to the Spectral Entropy, the SVDEn measure estimates the deviation of the singular values away from a uniform distribution – more complex systems are characterized by a spread of energy away from the first singular values.

Permutation Entropy (PE). This measure quantifies the diversity of orderings of symbols derived from a scalar time series $\{x_i\}_{i=1}^L$ by reordering the amplitude values (Bandt, Pompe, 2002; Staniek, Lehnertz, 2007). The permutation entropy of order $n \geq 2$ is defined as

$$H(n) = -\sum p(\pi) \cdot \ln p(\pi)/(n-1), \tag{18}$$

where the sum runs over all $n!$ permutations π of order n; $p(\pi)$ – the relative frequency of permutations. Permutation entropy is the Shannon entropy of n distinct symbols:

$$0 \leq H(n) \leq \ln n! /(n-1), \tag{19}$$

where the lower bound is attained for an increasing or decreasing sequence of values, and the upper bound for a completely random system (independent and identically distributed – i. i. d. sequence) where all $n!$ possible permutations appear with the same probability. Permutation entropy is an appropriate complexity measure for chaotic time series, in particular in the presence of dynamical and observational noise. Permutation entropies can be calculated for arbitrary real-world time series with a weak stationarity assumption (Bandt, Pompe, 2002). Since the method is extremely fast and robust, it seems preferable when there are huge data sets and no time for preprocessing and fine-tuning of parameters (Staniek, Lehnertz, 2007).

Base-Scale Entropy. First the time series are embedded in a d-dimensional space by Eq. For each d-dimensional vector, the base scale Z_{BS} is calculated by defining the base scale as the root mean square of the differences between every two contiguous data points in a d-dimensional vector (Li, Ning, 2006)

$$Z_{BS}(i) = \sqrt{\sum_{j=1}^{d-1}(x_{i+j} - x_{i+j-1})^2/(d-1)}. \tag{20}$$

Based on the base scale, the partition standard can be selected as a $\times Z_{BS}$ and each d-dimensional vector is transformed into a symbolic sequence on the basis of the four given levels alphabet (Li, Ning, 2006). The symbolic sequences S_i (d-words) at most have $4d$ different forms π since they are made up of four symbols, 0, 1, 2, and 3. The base-scale entropy of the d-dimensional vector is defined as

$$H(d) = -\sum P(\pi) \cdot log_2 P(\pi), \tag{21}$$

where $P(\pi)$ – the relative frequency for each π. The base-scale entropy method essentially quantifies the uncertainty of the occurrence of d-words form. The advantages of base-scale entropy are simplicity and extremely fast calculation for very short data sets. This method enables to analyze very short,

nonstationary, and noisy data series, so the base-scale entropy can be directly applied to real-world time series (Li, Ning, 2006).

Lempel-Ziv (LZ) algorithm. LZ complexity analysis is based on a coarse-graining of the measurements, so before calculating the complexity measure, the signal must be transformed into a finite symbol sequence (commonly into a 0–1 sequence) – the median, average and clusters conversion methods are used. LZ complexity is related to the number of distinct substrings and the rate of their recurrence along the given sequence, with larger values corresponding to more complexity in the data (Abasolo et al., 2006; Radhakrishnan et al., 2000). It is a nonparametric, simple-to-calculate measure of complexity in a one-dimensional signal that does not require long data segments to compute.

DISCUSSION AND CONCLUDING REMARKS

It is simple (and tempting) to borrow one of the developed appreoaches from another field that shares "key words" (Hristovski et al., 2010; Latash et al., 2010). This can provide tools that may help to find answers to questions after the questions have been formulated. The application of complex systems theory to sports is relatively new. Complex systems are well represented in their universal features by biological, evolutionary systems and that means that we can observe classes of behavior and transitions between those types of behavior that do not depend on the details of the system that is studied (Mayer, 2001). The methods applying to human data analysis are very important because many crucial variables are not directly measurable or even identifiable (Torrents, Balagué, 2006; Latash et al., 2010; Poderys et al., 2010). All the above-named and other algorithms of complexity measuring are used to compute the regularity of time series and classify the time series as being of one type or another on this basis. Entropy-based regularity and complexity measures have

been highly effective in analyzing a broad range of physiological signals (Karmakar et al., 2012). In many biological applications, they have been used to distinguish "healthy" from "unhealthy" biological signals or may serve as a non-invasive, objective means of determining physiological changes under steady or non-steady state conditions such as competition or acute clinical pathologies. As an extension of these applications, the problem of continuous health monitoring is considered, where the time series is not a fixed and complete set, but is "streaming." If we can associate a change in signal complexity with a change in the health of the system, then we might hope that entropy like measure might detect a developing problem (and possibly provide some warning before system failure) (Goldberger et al., 2002; Hristovski, Balagué, 2010). The choice of the particular entropy estimator is determined by the goal type, the capability of estimators in characterizing the constraints on a physiological time series, its robustness to noise considering the above-mentioned advantages and disadvantages of particular algorithms.

There is a fundamental problem with the scientific approach in that it requires abstraction and simplification in order to be formalized in a mathematical model. The process of simplification and abstraction has been extremely successful in describing the physical world but up to now it is not so clear if the same analytical approach could be always successfully applied to living objects (Mayer, 2001; Torrents, Balagué, 2006). For example, multiscale entropy has been widely used to quantify a system's complexity by taking into account the multiple time scales inherent in physiologic time series (Blasco-Lafarga et al., 2010; Hu, Liang, 2012). The multiscale analysis of physiologic time series such as the RR interval time series has revealed that the entropy differs according to the scale (Cysarz et al., 2011). It is difficult to apply analytical solutions in analysis of behavior of living, learning, and evolving systems and new approaches and solutions remain on the agenda.

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FIZIOLOGINIŲ LAIKO EILUČIŲ KOMPLEKSIŠKUMO ĮVERČIŲ APŽVALGA

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Kompleksinių sistemų teorija teikia naujų galimybių tyrėjams moksliniu požiūriu vertinti organizmą, biologinių ar kitų besivystančių sistemų ypatybes. Pastaraisiais metais fiziologinių laiko eilučių kompleksiškumo įvertinimui pasiūlyta didelė metodų įvairovė. Entropijos vertinimo metodai vis plačiau taikomi fiziologinių laiko eilučių tyrinėjimų metu norint išreikšti kiekybinį jų sudėtingumą.

Tikslas – pateikti tyrėjams populiariausių kompleksiškumo įverčių (entropijos), taikomų biologijos, medicinos, sporto mokslų srityje, apžvalgą.

Rezultatai. Apžvalgoje supažindinama su populiariausais kompleksiškumo vertinimo metodais (imties entropijos (angl. *Sample Entropy*), kontrolės entropijos (angl. *Control Entropy*), spektro entropijos (angl. *Spectral Entropy*), vilnelių entropijos (angl. *Wavelet Entropy*), dekompozicijos singuliarinėmis reikšmėmis entropijos (angl. *Singular-Value Decomposition Entropy*), perstatinių entropijos (angl. *Permutation Entropy*), pagrindinės skalės entropijos (angl. *Base-Scale Entropy*), entropijos pagal Lempel-Ziv algoritmą (angl. *Entropy based on Lempel-Ziv algorithm*)), apibūdinami pagrindiniai jų ypatumai ir taikymo sritys.

Aptarimas ir išvados. Įvairūs entropijos vertinimai gali būti taikomi tyrinėjant sudėtingų kompleksinių, adaptatyvių sistemų elgsenos ypatybes, tačiau pasirenkant vertinimo būdą svarbu atsižvelgti į pasirinkto algoritmo pranašumus ir trūkumus, vertinamo proceso (laiko eilučių) ypatybes. Analitiniai gyvų sistemų tyrinėjimai yra pakankamai sudėtingas uždavinys, todėl naujų požiūrių ir sprendimų paieška tebelieka aktualiu nūdienos mokslų uždaviniu.

Raktažodžiai: fiziologinės laiko eilutės, kompleksiškumas, entropija.

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RELATIONSHIP BETWEEN ATHLETES' VALUES AND MORAL DISENGAGEMENT IN SPORT, AND DIFFERENCES ACROSS GENDER, LEVEL AND YEARS OF INVOLVEMENT

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ABSTRACT

Research background and hypothesis. The research focuses on university athletes' values and moral disengagement in sport. Hypothetically moral and competence values would negatively correlate with moral disengagement in sport. Also, values in sport would differ across gender and sports mastery.

Research aim was to examine the relationship between athletes' values and moral disengagement in sport, and to determine the manifestation of athletes' values and moral disengagement in sport by gender, sports mastery and sports experience.

Research methods. The sample included 318 athletes recruited from Lithuanian universities. The participants completed the Youth Sport Value Questionnaire-2 (YSVQ-2; Lee et al., 2008) and the Moral Disengagement in Sport Scale-Short (MDSS-S; Boardley, Kavussanu, 2008).

Research results. The positive correlation between values in sport and negative correlation between moral values and moral disengagement in sport were established. Moral values were more important to females compared to males ($p < 0.01$). Competence values were more important to international level athletes compared to the national level athletes ($p < 0.01$). ANOVA indicated the differences of years of involvement in sport in dependence on moral values ($p < 0.05$) and competence values ($p < 0.01$).

Discussion and conclusions. Research established negative correlation between moral values and moral disengagement, but there were no correlations with status values. The study confirmed the hypothesis that female athletes' scores on moral values would be higher comparing to those of male, but there were no differences comparing moral disengagement in sport. Athletes of higher levels of competition (international level athletes) scored higher on competence values. Research supported the hypothesis that athletes' moral disengagement in sport would not differ across sport experience.

Keywords: sport, athletes' moral behavior, values in sport, moral disengagement in sport.

INTRODUCTION

Values are defined as beliefs that certain goals or behaviors are more or less preferable to their alternatives (Rokeach, 1973). They serve the interests of individuals or groups, motivate action by giving it direction and intensity, provide standards by which behavior is evaluated, and are learned by individuals from the dominant values of their social groups and through their own experiences (Schwartz, 1994). Values can be organized in terms of system and structure. So, individuals and societies develop value systems in which values are ranked in importance (Rokeach, 1973). The evaluation of the role of values when behavioral decisions are made has received much attention from scientists. However, values have been underestimated in sport psychology (Lee et

al., 2008). In sport, they might include not only criteria of success, such as winning or playing well, but also fair play, sportsmanship, friendship, and tolerance, which are concerned with the quality of interaction during the activity (Lee et al., 2000).

On the other hand, the attitudes towards sport and its values have been changing in modernizing society (Budreikaitė, Adaškevičienė, 2010). In this way traditional values in sport give way to consumer values (Genys, 2011). No coincidence, negative social behaviors, such as intentionally injuring an opposing player, cheating, and retaliating to a bad foul, are common in sport (Kavussanu, et al., 2006). In this context the relevant question is why people get engaged in negative behaviors. Athletes can be under pressure to engage in transgressive acts in order to justify the expectations of a coach, parents and even sponsors aiming at capturing the leadership position in the team, etc. As I. D. Boardley and M. Kavussanu (2007) suggest, "players are often evaluated based on the outcomes of their actions rather than the means through which they achieve them" (p. 609). Though some theories claim that the actions performed are linked to certain emotions (guilt or pride), which regulate future behavior anticipatorily, some individuals do not always act the way they should (Bandura, 1991). A. Bandura (1991) suggests that people are able to violate personal standards without self-sanction through the selective use of eight psychosocial maneuvers known as mechanisms of moral disengagement. These mechanisms allow individuals to transgress without experiencing negative affect, thereby decreasing constraint on future negative behavior. It should be noted that moral disengagement in sport context has received researchers' attention only during the last several years. It was established that moral disengagement had strong positive relationship with antisocial behavior towards both teammates and opponents (Boardley, Kavussanu, 2007, 2009) and with perceived value of toughness (Boardley, Kavussanu, 2010). It was also established that moral disengagement mediated relationship between controlled motivation and antisocial behavior toward teammates and opponents (Hodge, Lonsdale, 2011). Some recent studies have found that prosocial attitudes in sport are predicted positively by moral and competence values, whereas antisocial attitudes are predicted positively by status and negatively by moral values (Lee et al., 2008).

The data mentioned above induce further research aiming at two research targets. Firstly – to examine whether there is a relationship between athletes' values and moral disengagement in sport. Secondly – to determine the manifestation of athletes' values and moral disengagement in sport and their dependence on athletes' gender, sports mastery and sports experience. In this study we extended previous research on moral behavior in sport by (1) examining athletes' values in sport and their relationship with moral disengagement, and (2) evaluating values and moral disengagement in sport by athletes' personal factors (gender, sports mastery and years of involvement in sport; and (3) our study involved university athletes as previous research often involved adolescents.

We hypothesized (H1) that moral and competence values would be negatively correlated with moral disengagement in sport, and status values would be positively correlated with moral disengagement in sport. Also we hypothesized (H2) that female athletes' scores on moral values would be higher than those of males, and scores on moral disengagement would be lower. Athletes' values but not moral disengagement in sport will differ across sports mastery (H3). Athletes' values and moral disengagement in sport will not differ across sports experience (H4).

RESEARCH METHODS

Research participants. The sample included 318 (237 male and 81 female) athletes recruited from Lithuanian universities. The condition of athletes' participation in our research was previous participation in a championship of the country, i. e. we tended to recruit athletes of higher sports mastery levels. For that reason we applied purposive sampling. Among the athletes who participated in this study, 52.5% noted that they were prize-holders in the national championship, 22.6% of them participated in the European Championship and 6.0% – in the World Championship. While analyzing the data athletes were divided into two groups by their sports mastery: National level (who participated only in the national championship) and International level (who participated in European or World Championship). Among the research participants, 68.5% played various ball games (basketball, volleyball, handball and football), 11.0% were in track and field events, and 21.5% were in other sports, mainly in individual sports. Years of involvement in their current sport ranged

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from < 1 to 20 (M = 9.43, SD = 3.38). While analyzing the data athletes were divided into three groups based on percentiles of their sport experience: ≥ 7-year experience (n = 89), 8–11-years of sport experience (n = 128), and ≤ 12-year sport experience (n = 101).

Measures. The survey-style assessment questionnaire was used in this study and it contained three sections. The first requested the participants' gender, most recent sport, and years of involvement in that sport. The other sections assessed athletes' values and moral disengagement in sport. Each specific scale is described below.

The Youth Sport Values Questionnaire-2 (YSVQ-2; Lee et al., 2008). The 13-item questionnaire was headed *What is important to me in sport* and respondents were asked to "Please circle one of the numbers beside each item to show how important it is to you in your main sport." Responses produced were produced on a 7-point scale with the following response labels, each starting with the phrase "This idea is. "*extremely important to me* (5), *very important to me* (4), *important to me* (3), *quite important to me* (2), *slightly important to me* (1), *not important to me* (0), and *the opposite of what I believe* (−1). The YSVQ-2 included three-factors (moral, competence, and status values) that were confirmed with the Lithuanian version of this questionnaire (Šukys, 2010). Alpha coefficients showed good-to-very-good levels of internal consistency and ranged from 0.89 to 0.79.

The Moral Disengagement in Sport Scale-Short (MDSS-S; Boardley, Kavussanu, 2008). This eight item scale measured overall construct of sport moral disengagement. Items were rated on a 7-point scale anchored by strongly disagree (1) and strongly agree (7). Examples of items were *"It is okay for players to lie to officials if it helps their team", "Shouting at an opponent is okay as long as it does not end in violent conduct", "A player should not be blamed for injuring an opponent if the coach reinforces such behavior"*. Although this scale was a unidimensional measure of sport moral disengagement, but it still had items measuring eight of the mechanisms of moral disengagement. However, in this study overall sport moral disengagement was of interest. Alpha coefficient for the overall scale was acceptable (0.70).

Statistical analysis. Statistical analysis of the data was performed using *SPSS-13.0 package for Windows*. After conducting descriptive statistical analysis, the internal consistency of the subscales was examined by conducting Cronbach's alpha analyses. Pearson's correlation coefficient was applied to identify correlations among the subscales. The statistical or null hypothesis (Ho) of equality of the mean (M) between groups was tested using independent sample t-test and One-Way ANOVA. In all instances (comparing more than two groups) where the Ho was rejected, post-hoc (Turkey test) was computed. In calculating the effect size (η^2) for independent samples in a t-test the following formula was used: $\eta^2 = t^2/(t^2 + df)$. For the analyses of variance the effect size was calculated: η^2 = Sum of squares between groups/ Total sum of squares. In interpreting effect size the guidance from J. Cohen (1988) was taken into account: 0.01–0.05 very small effect, 0.06–0.14 moderate effect and from 0.15 very large effect.

RESEARCH RESULTS

Descriptive statistics and correlations were computed using the entire sample and presented in Table 1. Athletes reported competence values the most, followed by moral and status values, respectively. Mean value for moral disengagement in sport shows that athletes more often tend to choose neutral position when evaluating eight statements related with behavior in sport. Significant correlations were r = 0.54 between moral and competence values, r = 0.62 between competence and status values, and r = 0.33 between status and moral values. As it was hypothesized, sport moral disengagement was negatively related with moral values, but there were no correlation with competence and status values.

Next we explored differences by athletes' gender, mastery, and years of involvement in sport (Tables 2, 3). Females' mean scores were significantly higher than those of males on moral values *(*t (316) = 2.51, p < 0.01). Research results did not reveal statistically significant differences comparing overall moral disengagement in sport by gender. There were no differences comparing the evaluations of each eight statements by gender separately. The mean scores on competence values of international level athletes were significantly higher than those of athletes who participated in the national level contests (t (316) = 2.50, p < 0.01). There were no statistically significant differences comparing both overall moral disengagement in sport scores and each statement separately.

Table 1. **Correlations, reliability estimates, and descriptive statistics for the YSVQ-2 and MDSS-S (n = 318)**

Variables	1	2	3	4
1. Moral values	(0.79)			
2. Competence values	0.54**	(0.89)		
3. Status values	0.33**	0.62**	(0.79)	
4. Moral disengagement	−0.24**	−0.02	0.06	(0.70)
Mean	3.78	4.06	3.43	3.51
Standard deviation	0.83	1.04	1.17	1.08

Note. ** – $p < 0.01$. Alpha coefficients are reported on the diagonal.

Table 2. **Means, SD, and effect size of youth sport values and moral disengagement in sport by athletes' gender and mastership (n = 318)**

Variables	Gender					Mastership				
	Female (n = 81)		Male (n = 237)			National level (n = 236)		International level (n = 82)		
	M	SD	M	SD	h²	M	SD	M	SD	h²
Moral values	3.98	0.72	3.71	0.86	0.02 **	3.78	0.83	3.80	0.83	0.001
Competence values	4.04	0.99	4.06	1.06	0.001	3.97	1.02	4.30	1.05	0.02 **
Status values	3.26	1.24	3.50	1.14	0.01	3.39	1.21	3.56	1.02	0.004
Moral disengagement	3.50	1.07	3.51	1.10	0.001	3.45	1.06	3.65	1.16	0.007

Note. ** – statistically significant difference ($p < 0.01$).

Table 3. **Means, SD, and effect size of youth sport values and moral disengagement in sport by the year of involvement in sport (n = 318)**

Variables	Years of involvement in sport					
	≥ 7-year experience (n = 89)		8–11-year experience (n = 128)		≤ 12-year experience (n = 101)	
	M	SD	M	SD	M	SD	h²
Moral values	3.68	0.96	3.94	0.69	3.71	0.77	0.02 *
Competence values	3.85	1.23	4.26	0.80	4.02	1.01	0.03 **
Status values	3.24	1.28	3.54	1.12	3.45	1.14	0.01
Moral disengagement	3.36	1.06	3.54	1.11	3.58	1.09	0.001

Note. * – statistically significant difference ($p < 0.05$). ** – statistically significant difference ($p < 0.01$).

ANOVA indicated the differences of years of involvement in sport in dependence on moral values ($F (2, 316) = 3.60$, $p < 0.05$). The Turkey test found that the means for ≥ 7-year involvement in sport, and eight to 11 years of involvement in sport were statistically significantly different from each other ($p < 0.05$), and that there were no other statistically significant differences comparing the mean values between other groups of athletes. ANOVA indicated the differences in the years of involvement in sport on competence values, respectively ($F (2, 316) = 4.55$, $p < 0.01$). The Turkey test found that the means for ≥ 7-year involvement in sport and eight to 11 years of involvement in sport were statistically significantly different from

each other ($p < 0.01$), and that there were no other statistically significant differences comparing the mean values between other groups of athletes.

DISCUSSION

Our research purposes were, first, to examine the relationship between university athletes' values and moral disengagement in sport. It was hypothesized that moral and competence values would be negatively correlated with moral disengagement in sport. Research results partly confirmed this hypothesis as we established a negative correlation between moral values and moral disengagement, but there were no correlation with competence

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values. It should be noted that our hypothesis was based on other studies which indicated that moral disengagement in sport correlated with antisocial behavior (Boardley, Kavussanu, 2007, 2009) and antisocial attitudes correlated with status values (Lee et al., 2008). It is worth noting that this study did not reveal positive relations between status values and moral disengagement in sport. However, in previous studies no relation between status values and antisocial behavior of students engaged in sports was established either (Šukys, 2010). But moral disengagement in sport could be as mediator when examine relationship between athletes values and actual behavior.

The second purpose of our research was to examine the manifestation of athletes' values and moral disengagement in sport in dependence of gender, sports mastery and years of experience in sports. Our research only partly confirmed the hypothesis that female athletes' scores on moral values would be higher than those of male, and scores on moral disengagement were lower, on the contrary. Though moral values were more important to females engaged in sports compared to males, but the established effect of size was very low. Besides, female athletes' scores on moral disengagement in sport were not lower than those of male. This does not confirm the results of other studies which found that men displayed higher levels of moral disengagement than women (Boardley, Kavussaanu, 2007). Our data also indirectly contradicted to the findings of other research that sport moral maturity differed significantly across gender, with female athletes having higher moral reasoning scores than male athletes (Miller et al., 2004). Those differences can be explained by the fact that sport is traditionally male domain and stereotypic expectations of masculinity are believed to influence male sport behavior (Greendorfer, 1993; Schissel, 2000). Besides, masculinity is related with perceived value of toughness, especially in some contact sports (Shissel, 2000; Burgess et al., 2003). Some recent studies indicated that perceived value of toughness had indirect positive effects on antisocial behavior toward opponents and teammates (Boardley, Kavussanu, 2010). However, the latter researchers note that athletes from different sports display different levels of morality, e. g. in moral disengagement is higher in soccer than in basketball, hockey, and netball (Boardley,

Kavussanu, 2007). More than one third of our research sample were students playing basketball, thus we did not compare our findings according to the branches of sports. Besides, the number of females in our study was markedly less compared to males. Thus, further research examining moral disengagement in sport should focus on gender in the comparisons of athletes in different branches of sports.

It was hypothesized that athletes' values but not moral disengagement in sport would differ across sports mastery. Our findings confirmed this hypothesis only partly because athletes of higher levels of competition (international level athletes) scored higher on competence values. It means that in sport for them is much more important to become a better athlete, use own personal skills well, set own targets, and improve their performance. It should be noted that there were differences in the evaluations of different competences, but the effect size was very low. On the other hand, it was confirmed that athletes' moral disengagement in sport would not differ across sports mastery.

Our research partly confirmed the hypothesis that athletes values in sport would not differ across sport experience. According to the data of our research, both moral and competence values were equally important to athletes with both the least and the greatest sports experience. However, 8–11-year-old athletes produced different results, as the values mentioned above were more important for them. We suggest that when athletes gain more experience in their sports, moral and competence values become more important to them, but later their significance decreases. Research supports the hypothesis that athletes' moral disengagement in sport would not differ across sport experience. Such presumption was based on previous research that sport experiences are not associated with antisocial behavior (Boardley, Kavussanu, 2010). Nevertheless, some recent studies suggested that sport experience positively predicted antisocial behavior in sport (Sagar et al., 2010). In the context of our research we should note that the research participants were adult athletes. We suppose that our hypothesis might not have been confirmed in the study of children as other research has indicated that sport experience factor could be more important examining children's moral behavior in sport (Lee et al., 2007).

CONCLUSION AND PERSPECTIVES

Our research established negative correlation between moral values and moral disengagement, but there were no correlations with competence and status values. The study only partly confirmed the hypothesis that female athletes' scores on moral values would be higher than those of male. However, we did not confirm the supposition that female athletes' scores on moral disengagement in sport would be lower than those of male. Athletes of higher levels of competition (international level athletes) scored higher on competence values. Research supported the hypothesis that athletes' moral disengagement in sport would not differ across sport experience, but did not confirm the supposition about differences in values in sport.

Although previous research examined the relationship between moral disengagement and antisocial behavior in sport (Boardley, Kavussanu, 2007, 2009; Hodge, Lansdale, 2011), the role of values was underestimated. Further research should verify the hypothesis about moral disengagement in sport being as mediator when examining the relationship between athletes' values and actual behavior.

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RELATIONSHIP BETWEEN ATHLETES' VALUES AND MORAL DISENGAGEMENT IN SPORT, AND DIFFERENCES ACROSS GENDER, LEVEL AND YEARS OF INVOLVEMENT

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VERTYBIŲ BEI MORALINIO PATEISINIMO SPORTINĖJE VEIKLOJE TARPUSAVIO RYŠIAI IR RAIŠKA SPORTININKŲ LYTIES, MEISTRIŠKUMO IR SPORTINĖS PATIRTIES POŽIŪRIU

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tyrimu buvo gilinamasi į universitetų studentų vertybes ir moralinio pateisinimo sportinėje veikloje problematiką. Keliama hipotezė, kad moralinės ir gebėjimų ugdymo vertybės neigiamai koreliuoja su moraliniu pateisinimu sportinėje veikloje. Taip pat tikimasi, kad sportuojančių studentų vertybės sportinėje veikloje skirsis pagal lytį ir sportinį meistriškumą.

Tikslas – išsiaiškinti sportuojančių studentų vertybių ir moralinio pateisinimo sportinėje veikloje tarpusavio ryšius ir raišką lyties, sportinio meistriškumo ir sportinės patirties požiūriu.

Metodai. Tiriamųjų kontingentą sudarė 318 sportuojančių studentų, parinktų iš įvairių Lietuvos universitetų. Tiriant studentus naudoti: Jaunimo vertybių sportinėje veikloje klausimynas-2 (YSVQ-2; Lee et al., 2008) ir Moralinio pateisinimo sportinėje veikloje trumpoji skalė (MDSS-S; Boardley, Kavussanu, 2008).

Rezultatai. Nustatyta teigiama koreliacija tarp atskirų vertybių grupių, o neigiamas ryšys – tarp moralinių vertybių ir moralinio pateisinimo sportinėje veikloje. Sportuojančioms merginoms, lyginant jas su vaikinais, moralinės vertybės sportinėje veikloje svarbesnės (p < 0.01). Didesnio meistriškumo sportininkams sportinėje veikloje svarbesnės gebėjimų ugdymo vertybės (p < 0.01). Moralinių (p < 0.05) ir gebėjimų ugdymo (p < 0.01) vertybių reikšmingumas sportinėje veikloje skiriasi priklausomai nuo sportuojančių studentų sportinės patirties.

Aptarimas ir išvados. Tyrimas atskleidė: tarp moralinių vertybių ir moralinio pateisinimo sportinėje veikloje egzistuoja neigiamas ryšys. Nepasitvirtino prielaida, kad tarp statuso vertybių ir moralinio pateisinimo sportinėje veikloje turi būti teigiamas ryšys. Sportuojančioms merginoms sportinėje veikloje svarbesnės moralinės vertybės, tačiau nenustatytas skirtumas vertinant moralinio pateisinimo sportinėje veikloje rezultatus pagal lytį. Skirtingo meistriškumo sportuojančių studentų vertybių sistema sportinėje veikloje skiriasi. Pasitvirtino hipotezė, kad moralinio pateisinimo sportinėje veikloje duomenys skirtingos sportinės patirties grupėse nesiskiria.

Raktažodžiai: sportinė veikla, moralinis elgesys sportinėje veikloje, vertybės sportinėje veikloje, moralinis pateisinimas.

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WHOLE BODY CRYOTHERAPY AND ADAPTIVE REACTIONS OF THE HUMAN ORGANISM IN THE ASPECT OF COMPLEX SYSTEM THEORY

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ABSTRACT

Research background and hypothesis. The research focuses on changes of different ECG parameters and their concatenations during the whole body cryotherapy procedure.

Research aim was to evaluate the changes in the relationships and complexity of the human organism systems by analyzing different ECG parameters and their dynamical concatenations during the whole body cryotherapy procedure.

Research methods. The sample included 24 volunteers without cardiovascular diseases who received whole body cryotherapy treatment course which consisted of 7 procedures per person on average. The 12-lead standard ECG was registered using computerized ECG analysis system "Kaunas-Load". ECG was registered continuously 1 min before, during the procedure and 3 min after the procedure.

Research results. Regulatory system is activated on all fractal levels during cryotherapy procedure. This is reflected by changes of measured durational parameters: RR, JT, dQRS. Significant changes in the supplying system (ST segment position) were not observed. Significant changes of metabolic processes (T-wave amplitude) at organ and cell levels can be observed during the recovery after the procedure. Changes in ECG parameter concatenations show that first the regulatory system reacts on the organism level (RR/JT), neurohumoral system is activated during the procedure and interactions between systems (RR/dQRS) and interactions in the organ and cell levels (JT/dQRS) increase during the recovery period after the procedure.

Discussion and conclusions. Whole body cryotherapy causes changes in ECG parameters and their concatenations which represent adaptive organism reactions and activation of all organism adaptive resources. The data show the safety of the procedure from the coronary, as well as hemodynamic point of view of other organs.

Keywords: cryotherapy, complex system theory, concatenation between ECG parameters.

INTRODUCTION

Cryotherapy [kryos – cold, therapy – treatment (gr.)] – is a method of physiotherapy treatment, that is based on using cold, as the main physical factor impacting human's body's surface. Cryotherapy is cooling of whole organism or parts of it with extremely cold gases (–130, –160ºC).

Pioneer of cryotherapy Japanese physician Tosimo Jamauchi started to apply this method to treat rheumatoid arthritis in 1978. Since 1985, cryotherapy was introduced in Germany, and in 1989 – Poland (Sieron, Ciesar, 2007 a). Cryotherapy is now widely used in Europe in Germany, Poland, Russia, Ukraine, Czech Republic, Latvia and others. In Lithuania cryotherapy as a therapeutic procedure is known to few, it was introduced in 2005. Lithuania is only just starting to investigate the effectiveness of the procedure and the impact of it on a human body.

Versatility and high therapeutic efficacy of cryotherapy as physiotherapy procedure, determine the spreading of this method into all areas of medicine, as well as in sports medicine. The primary goals of cryotherapy in sports medicine – traumatic pain reduction, activation of regeneration processes, toning, and fatigue-reducing effects of cryotherapy. It has been shown that with the use of cryotherapy, it is possible to improve athletes' performance. Cryotherapy has a non-specific stimulatory effect, activates the body's self-repairing reactions. In some cases, the same technique of cryotherapy can be used to treat two opposite diseases, such as allergy and immune deficiency-cryotherapy returns to normal immune system activity (Апрелева, Баранова, 2007).

Effects of cryotherapy are studied in different aspects. Its efficiency for the treatment of various diseases can be evaluated by surveys and tests, also by monitoring changes of various biochemical indices. In sports medicine cryotherapy is studied for the better understanding of its impact on a common well-being of athletes and their exercise tolerance (Joch, 2004).

Majority of research results suggest, that the mechanism of cryotherapy effect is based on stressogenic reactions, in the body i. e. result of the activation of adaptive resources of all major body systems – thermoregulatory, immune, endocrine, cardiovascular, respiratory, neurohumoral (Lyakh et al., 2009).

Adaptive processes in the human body can be evaluated on the basis of complex systems theory. Complex system science is a field of science that deals with the general properties of systems, which are treated as complex in its nature/character, organization and management (Erdi, 2008), i. e. science that deals with how the links of separate parts of system impacts behavior of all system and how the system interacts with the environment (the scope of complex system in medicine is called "Systems medicine", in biology –"Systems biology").

In this respect there are several holistic systems in the human body: skeletal – muscle system (we call it peripheral system – P), cardiovascular system (supplying system – S) and regulatory system (R). These three systems are called holistic because they interact with every cell in the human organism. When organism adapts to the changing environment, all three systems react in conjunction (during every adaptation in different form and degree) and a whole body reaction is always a result of cumulative responses of these three systems

(Berškienė, 2010). There are functional synergistic relationships (interactions) among these systems, so the body works as one integral unit. The developed model helps to evaluate the integrity of the body and reveals the essential functional relationships (Vainoras et al., 2008).

Human body systems can be analyzed at different levels of complexity (molecules, cells, tissues, organs, systems), and physiological data analyzed on several levels show the complexity, fractality, interrelations and dynamic links in the system.

Speaking about the human body as a complex system and its properties, the main system which affects the functionality of whole organism at many levels, is the cardiovascular system. Looking at the human body as an adaptive integrated system, cardiovascular system is a "convenient" system, which interacts with all systems in the organism and represents all its functionality with electrical processes (ECG) (Berškienė, 2010). ECG represents the functioning of the heart at all its levels: heart rate variations (RR) well characterize regulatory processes, cardiac electrical systole duration (JT) is related to cardiac metabolic processes (lower level of complexity – process duration is up to 500 ms). Shorter processes, such as QRS complex duration (dQRS), characterize regulatory cardiac conduction system processes (duration up to 100 ms) (Žemaitytė, 1997). It is important to evaluate not only ECG parameters, but also the changes of their concatenations also, which reflects not only changes at certain levels, but also the dynamic relationships between these levels (Berskiene et al., 2009).

The aim of this study was to evaluate the changes in the relationships and complexity in the systems of the human organism which represents adaptive organism reactions by analyzing different ECG parameters and their dynamical concatenations during whole body cryotherapy procedure.

Hypotheses: H_o: Whole body cryotherapy does not cause changes in ECG parameters and their concatenations. H_1: Whole body cryotherapy causes changes in ECG parameters and their concatenations.

RESEARCH METHODS

ECG parameters and their concatenations changes during cryotherapy procedure were recorded using the original ECG analysis system

"Kaunas–Load" and reflect not only the changes in the cardiovascular system but also adaptive reactions of the whole body.

24 volunteers without the history of cardiovascular diseases participated in this study. The average age was 52.2 ± 11.7 (from 20 to 72 years old). There were 9 women (average age 53.3 ± 5.5 y.) and 15 men (average age 51.5 ± 14.4 y.). They received whole body cryotherapy treatment course which consisted from 4 to 14 procedures, 7 procedures per person on average.

An open top personal cryosauna in which, with the aid of liquid nitrogen vapors, the -160°C temperature was used for the procedures. Procedures where carried out on a daily basis. The length of the first procedure was 100 s, and then the length of each next procedure was 5–10 s longer. The maximum exposure time was 3 minutes (180 s). The 12-lead standard ECG was registered using computerized ECG analysis system "Kaunas–Load". ECG was registered continuously 1 min before each procedure, during the whole procedure and 3 min after the procedure.

ECG parameters where analyzed in lead II on a computer screen with the help of high sensitivity electronic ruler. Noises caused by the electrical circuit, breathing and motions where filtered using ECG filters. Parameters examined: before procedure (1), during procedure (2) and during the recovery (3 minutes after the procedure) period (3), interval RR (RR1, RR2, RR3), interval JT (JT1, JT2, JT3), QRS (dQRS1, dQRS2, dQRS3), amplitude ST (AST1, AST2, AST3), amplitude R (AR1, AR2, AR3) and T (AT1, AT2, AT3) wave amplitudes, and arterial blood pressure before the procedure and after it. We also evaluated concatenations of ECG parameters: RR/JT (RR/JT1, RR/JT2, RR/JT3), JT/dQRS (JT/dQRS1, JT/dQRS2, JT/dQRS3), RR/dQRS (RR/dQRS1, RR/dQRS2, RR/dQRS3), R/T (AR/AT1, AR/AT2, AR/AT3), T/ST (AT/AST1, AT/AST2, AT/AST3), R/ST (AR/AST1, AR/AST2, AR/AST3).

The data were processed using SPSS 17.0. To evaluate general changes of ECG parameters, in each test arithmetic averages of subject's ECG parameters were calculated. The pairs of ECG parameters compared were as follows: before the procedure and during the procedure, during the procedure and during the recovery period, before the procedure and during the recovery period after it, i. e. RR1-RR2, RR2-RR3, RR1-RR3, JT1-JT2, JT2-JT3, JT1-JT3 and etc., systolic and

diastolic blood pressure before the procedure (1) and after it (2), i. e. SBP1-SBP2, DBP1-DBP2 and concatenations of parameters RR/JT1-RR/JT2, RR/JT2-RR/JT3, RR/JT1-RR/JT3 etc. A continuous record of all parameters was measured in the same sections and the averages of series of cardio cycles were measured.

In the perspective of complex system theory, acting peripheral system (P) was evaluated by pulse pressure, the Regulatory system (R) was evaluated by RR interval, and the Supplying system (S) was evaluated by JT interval. JT interval changes are directly related to the heart metabolism processes, QRS complex duration reflects the regulatory system features (conduction) of heart itself, T wave amplitude is connected to intrinsic heart metabolic processes.

According to normal physiology, we postulate, that interval RR (RR1, RR2, RR3), reflect the changes in regulatory system function (level of whole human organism), JT (JT1, JT2, JT3) reflect changes in metabolism of the heart, and duration QRS (dQRS1, dQRS2, dQRS3) reflect changes in the regulatory system of the heart (conduction features of the heart), ST segment amplitude (AST1, AST2, AST3) reflects the effectiveness of coronary blood supply, R wave amplitude (AR1, AR2, AR3) and T wave (AT1, AT2, AT3) amplitudes are connected to intrinsic heart metabolic processes.

Concatenations of ECG parameters, intervals RR/JT (RR/JT1, RR/JT2, RR/JT3), reflects interrelations between regulatory and heart metabolic processes (whole organism level), JT/dQRS (JT/dQRS1, JT/dQRS2, JT/dQRS3) reflect interrelations between heart metabolic processes and intrinsic heart regulatory processes (sub systemic level), RR/dQRS (RR/dQRS1, RR/dQRS2, RR/dQRS3) reflect concatenation between two fractal levels – the organism and the subsystem.

We have investigated concatenations and other amplitude parameters, but their physiological interpretation still is not clear, AR/AT (AR/AT1, AR/AT2, AR/AT3) could be related to the breathing effectiveness, AT/ST (AT/AST1, AT/AST2, AT/AST3) could be related to the coronary hemodynamic, AR/AST (AR/AST1, AR/AST2, AR/AST3) could be connected to the interrelation between the breathing system and the effectiveness of coronary hemodynamic.

The normality of distribution of results was estimated using the Shapiro-Wilk test. The data

differed significantly from the normal distribution. In order to determine the significance of the differences between the examinations before, during and after the whole-body cryotherapy, non-parametric Wilcoxon test for paired samples was used. The significance level $p < 0.05$.

The study was carried out with Kaunas Regional Biomedical Research Ethics Committee Permission No. BE-2-50.

RESEARCH RESULTS

Durational and amplitude parameters and inter-parametric concatenation sample differences before cryotherapy procedure, during the procedure and during the recovery period after the procedure were assessed. All measured durational parameter values increased during the procedure and after it, but statistically significant differences ($p < 0.05$) occurred only during recovery, i. e. soon after procedure (Figure 1 a, b, c).

Amplitudinal parameters changed slightly differently. R-wave amplitude (AR) statistically significantly increased during the procedure ($p < 0.05$), statistically significantly decreased after the procedure ($p < 0.05$) and recovered its initial state soon after that, i. e. there were no statistically significant difference between R-wave amplitude before the procedure and after it ($p > 0.005$) (Figure 2 a). T-wave amplitude, like durational parameter

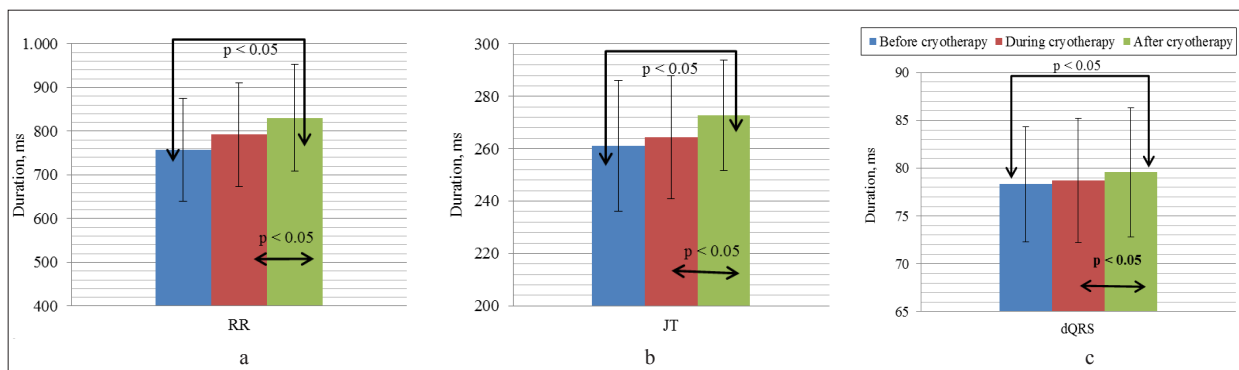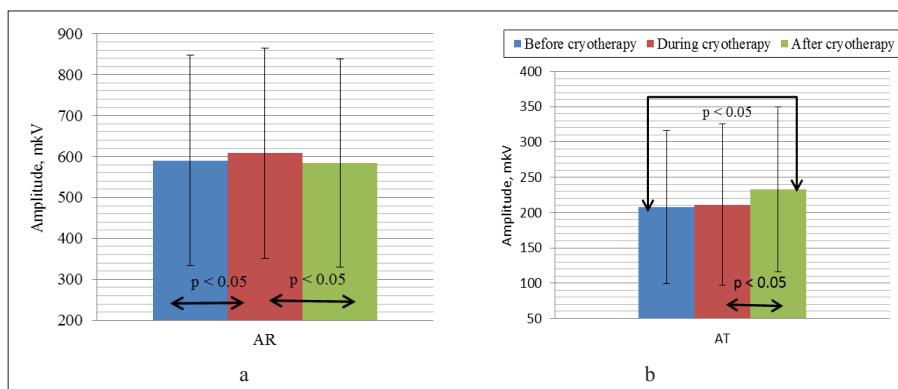Figure 1. **Changes in the duration of ECG parameters during whole body cryotherapy**

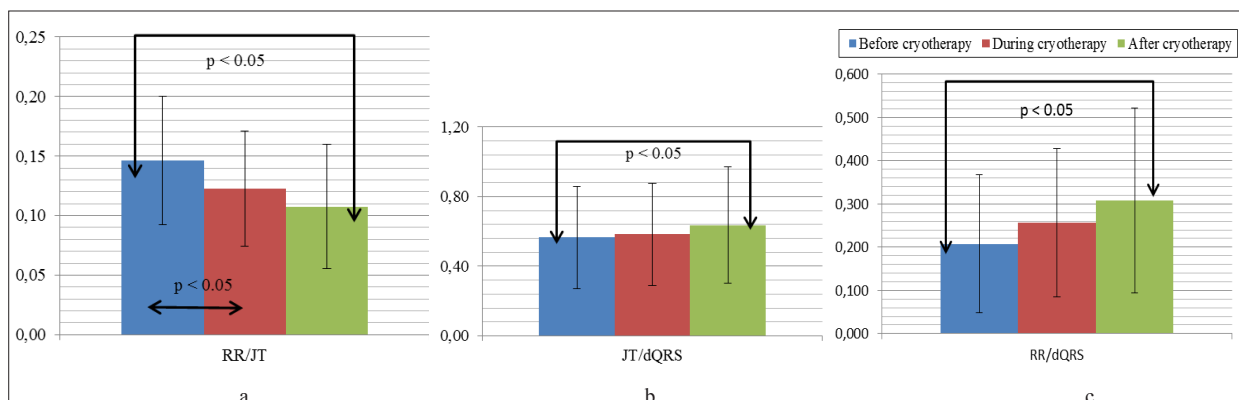Figure 2. **Changes in the amplitudes of ECG parameters during whole-body cryotherapy**

Figure 3. **Changes in the concanetanations of ECG parameters (intervals)**
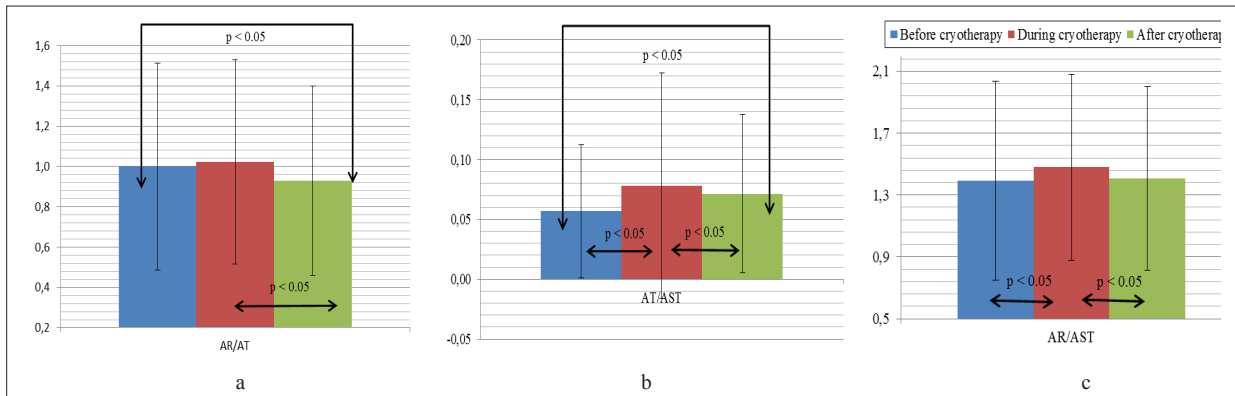
Figure 4. **Changes in the concanetanations of ECG parameters (amplitudes)**

values, increased during the recovery period (AT3) and statistically significantly ($p < 0.05$) differed from the initial T-wave amplitude value (AT1) (Figure 2 b). Significant ST segment depression was not observed in any of ECG registration stages ($p > 0.05$).

Statistically significant arterial blood pressure increase during cryotherapy procedure was observed. Systolic blood pressure increased from 129 ± 17.33 mmHg before cryotherapy procedure, to 139.00 ± 23.45 mmHg after it, diastolic – from 87.85 ± 10.15 mmHg to 90.33 ± 9.40 mmHg ($p < 0.05$).

To evaluate adaptive reactions of the body with inter-parametric concatenations (dimensionless values) is more important. These showed adaptive processes and intersystem communications taking place at various levels in the body.

All concatenations of durational parameters changed during cryotherapy procedure and statistically significant changes occurred during the recovery period soon after the procedure. Parameters RR/JT concatenation changes occurred sooner – statistically significant differences ($p < 0.05$) occurred during the procedure and remained during the recovery period after it (Figure 3 a). JT/QRS and RR/QRS parametric concatenations changed gradually and statistically significant differences were observed between the initial and recovery period values of these concatenations ($p < 0.05$) (Figure 3 b, c).

Concatenations of amplitude parameters changed differently. AR/AT concatenation numeric value increased during the cryotherapy procedure and significantly decreased after it, statistically significant differences were observed between AR/AT concatenation during the procedure

and soon after it, as well as the values between original AR/AT and AR/AT of the recovery period ($p < 0.05$) (Figure 4 a). AT/AST concatenation changed through all measured periods; significant differences were between all three pairs of concatenations: AT/AST1 –AT/AST2, AT/AST2-AT/AST3 and AT/AST1-AT/AST3 ($p < 0.05$) (Figure 4 b). AR/AST concatenation changed during the procedure, and recovered its initial state soon after it ($p < 0.05$) so there were no differences between the initial original and final AR/AST values ($p > 0.05$) (Figure 4 c).

The hypothesis H_o was rejected – whole body cryotherapy caused changes in ECG parameters and their concatenations.

DISCUSSION

Cardiovascular system reaction to short-term stress caused by extreme cold attracts attention of many researchers. In most cases they study variations in heart rate changes before the cryotherapy procedure and at different periods after it (by registering one – two standard lead ECG, ECG using 24h Holter's method). Usually analysis of ST segment, RR variability, systolic and diastolic blood pressure before cryotherapy and after the procedure, echoscopically assessing left ventricular ejection fraction before cryotherapy and after it are performed. There are no data available in literature how these parameters change during the procedure. Some authors point out that whole body cryotherapy does not cause any changes in hemodynamic parameters, such as heart rate, systolic and diastolic blood pressure (Sieron, Cieslar, 2007 b; Тетюра, 2009). Other authors shows increased arterial blood pressure (Lyakh et al., 2009; Lubkowska, Szygula, 2010),

decreased heart rate and increased stroke volume (SV), systolic index (SI) (Zalewski et al., 2011).

It is very difficult to systemize the results from various sources because the authors often confuse terms of cryotherapy and hypothermia, they often compare the results obtained in cold water with the results, obtained in cryogenic gases. The research of effects of cryotherapy shows, that optimal cryogenic temperature is –130, –160ºC. Temperature higher than –120ºC does not show any cryotherapeutic effect (Апрелева, Баранов, 2007). The fact that changes of hemodynamic parameters during cryotherapy were not seen in investigations can be explained by not enough low temperature (which has no cryotherapeutic effect) used for the procedure or too low sensitivity of recorded the parameters and analysis methods used.

Personal cryosauna that we used in our research meets temperature requirements (average temperature is –160ºC), and computerized ECG analysis system "Kaunas –Load" registers 12-lead ECG. Special filters installed in the program cancels all electrostatic, respiratory and movement caused noises. High sensitivity electronic ruler allows measuring all important ECG parameters and their concatenations, variability of these parameters, etc. precisely. On the basis on the changes in these parameters and their concatenations we can evaluate the organism responsive reactions to impacts of cryotherapy procedures.

According to the duration parameters changes we can suggest that the body reaction to extremely cold environment already starts during the procedure, although statistically significant differences in most parameters only become apparent during the recovery period after the procedure. Regulatory system reacts at all levels – systemic (RR), sub systemic (JT) and the organ (dQRS) levels. Amplitudinal parameters change slightly differently. R-wave amplitude increases during the procedure, possibly due to peripheral resistance and systolic index increase. T wave amplitude significantly changes during the recovery and that shows that cryotherapy induced metabolic processes changing in myocardium. There are no statistically significant ST-segment amplitude changes during cryotherapy, so in terms of coronary circulation processes the procedure is safe. The increase of blood pressure during cryotherapy procedure is reported by many researchers, but critical threshold for arterial blood pressure increase reported is no more than 20 mmHg (Lyakh et al., 2009) and it is completely normal that stress, caused by thermal procedure, increases ABP.

The change between parametric concatenations helps to assess body complexity and the main functional links even more than parameters alone. Changes in duration parameter concatenations show that regulatory (neurohumoral) system reacts in the first place at the systemic level. Significant RR/JT concatenation changes have been observed during the procedure. Decrease of RR/JT values represents decrease in systems complexity, i. e. increase of interaction between regulatory and supplying systems at the level of the human body. Increasing of JT/QRS and RR/QRS values indicate the increase of adaptation processes at organ and cell levels. Adaptive responses, activated during the procedure become even more pronounced during recovery period (Figure 3 a, b, c).

According to the changes in the amplitude parameter concatenations, we can conclude that respiratory function improves after cryotherapy procedure (changes of AR/AT concatenation) (Figure 4 a). Changes of blood circulation in organs were observed during all stages, i.e. circulation changes during the procedure and lasts during recovery after it (AT/ST) (Figure 4 b). Changes in the respiratory system and coronary hemodynamic were observed only during the procedure and their values returned to baseline levels after it (AR/AST) (Figure 4 c).

CONCLUSIONS AND PERSPECTIVES

Whole body cryotherapy – short term but intense irritation of the body surface with extremely low temperature – causes sharp adaptive reactions at all levels of an organism. These reactions can be detected by original ECG analysis method "Kaunas –Load" during all cryogenic exposure periods and the data obtained by this method can help explain human organism as an open adaptive complex system.

The obtained data confirm the data presented by other researchers, the safety of the procedure, and they reveal a deep interconnection between interactions not studied before, which determines positive therapeutic effects of whole body cryotherapy.

Cryotherapy affects the human body at the regulatory level, cardio metabolism level and organizational level of the heart itself – the organism reacts like a unified complexity system at all its fractal levels.

This method can be used to evaluate the effects of other therapeutic procedures on the human body widely used in health resort medicine (balneotherapy, peloidotherapy).

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BENDROJI KRIOTERAPIJA IR ORGANIZMO ADAPTACINĖS REAKCIJOS KOMPLEKSINIŲ SISTEMŲ TEORIJOS POŽIŪRIU

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tyrimu buvo gilinamasi į įvairių EKG rodmenų ir jų sąsajų pokyčius bendrosios krioterapijos procedūros metu.

Tikslas – ištirti ir įvertinti žmogaus organizmo sistemų kompleksiškumą analizuojant įvairių EKG rodmenų ir jų sąsajų pokyčius bendrosios krioterapijos procedūros metu.

Metodai. Buvo tiriami 24 savanoriai, nesergantys kraujotakos sistemos ligomis. Jiems taikytas bendrosios krioterapijos procedūrų kursas. Kiekvienam tiriamajam atlikta vidutiniškai po septynias procedūras. 12-os derivacijų EKG buvo užrašyta naudojant kompiuterizuotą EKG analizės sistemą „Kaunas–Krūvis". EKG registruota nenutrūkstamai vieną minutę iki procedūros, procedūros metu ir tris minutes po procedūros.

Rezultatai. Krioterapijos metu aktyvinama reguliacinė sistema visais fraktaliniais organizmo lygmenimis. Tai rodo matuotų trukminių rodmenų – RR, JT, dQRS – pokyčiai. Reikšmingų aprūpinamosios sistemos pokyčių (ST segmento padėtis) procedūra nesukelia. Organų ir ląstelių metabolinių procesų (T dantelio amplitudės) rodikliai po procedūros reikšmingai kinta. EKG rodmenų sąsajų pokyčiai rodo, kad pirmiausia reaguoja organizmo reguliacinė sistema (RR/JT) – jau procedūros metu aktyvinama neurohumoralinė sistema, o atsigavimo laikotarpiu stiprėja ląsteliniai ryšiai tarp sistemų (RR/dQRS) ir sąveikos organų (JT/dQRS).

Aptarimas ir išvados. Procedūra sukelia EKG rodmenų ir jų sąsajų pokyčius. Tai rodo adaptacinių organizmo reakcijų ir viso organizmo adaptacinių resursų aktyvaciją. Tyrimas patvirtina bendrosios krioterapijos procedūros saugumą tiek koronarinės, tiek ir kitų organų hemodinamikos požiūriu.

Raktažodžiai: krioterapija, kompleksinių sistemų teorija, EKG rodmenų sąsajos.

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THE RELATIONSHIPS BETWEEN MATURATION, PHYSICAL ACTIVITY AND OBJECTIFIED BODY CONSCIOUSNESS IN THE SAMPLE OF ADOLESCENTS

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ABSTRACT

Research background and hypothesis. Although trends of decline in physical activity during adolescence are determined by most authors, the association of biological maturation with physical activity has not been commonly studied. It is thought that the effect of changes occurring in adolescent physical activity during maturation may be associated with psychological factors, for instance, body dissatisfaction.

Research aim was to determine the relationships between maturation, physical activity and objectified body consciousness in the sample of adolescents.

Research methods. The study comprised adolescents of fifteen 9th forms of Kaunas education institutions (4 gymnasiums, 10 secondary schools and one main school). The studied sample consisted of 293 schoolchildren, 57 of them did not fill in questionnaires (because of refusal or absence). Thus the data of 236 students were analyzed, 115 (48.7%) of them were boys. Mean age (SD) of participants was 15 (0.38) years, the youngest was 14, the oldest – 16 years old. The anonymous questionnaires were used to determine physical activity, (*Leisure-Time Physical Activity Questionnaire,* LTPAQ; Godin, Shephard, 1985) objectified body consciousness (*Self-Objectification Questionnaire*, SOQ; Noll, Fredrickson, 1998) and the sexual maturation level of adolescents (*Tanner Sexual Maturation Scale*, SMS; Marshall, Tanner, 1969; Marshall, Tanner, 1970).

Research results. Late maturing adolescents were found only in the group of boys. Slightly more than one-third of boys and almost one-fifth of girls were early maturing. The analysis of association between the stage of maturation and adolescent physical activity showed a negative relationship in the group of adolescent boys. The study revealed that with an increase in sexual maturation stage girls reported higher rate of objectified body consciousness, however, this trend was not detected in boys. With an increase in maturation stage the rate of drive for thinness grew in girls and boys. Rates of body dissatisfaction, drive for thinness, objectified body consciousness were higher in adolescent girls than in boys, however, the rate of exercising was lower. Body dissatisfaction, drive for thinness, objectified body consciousness were not associated with physical activity in the sample of adolescents.

Discussion and conclusions. The study contributes to the research asserting that sexual maturation is associated with lower adolescent physical activity, however, it is common only among boys. Objectified body consciousness in girls and drive for thinness in both genders grow when sexual maturation increases. Rates of body dissatisfaction, drive for thinness, objectified body consciousness are higher in adolescent girls than in boys, however, their exercising rate is lower. Body dissatisfaction, drive for thinness, objectified body consciousness were not related to adolescent physical activity in the sample.

Keywords: maturation, physical activity, objectified body consciousness.

INTRODUCTION

Adolescence is one of the most complicated stages in human body development. This period is marked by rapid biological, psychological and social changes (Patton, Viner, 2007). Most researchers determined that

adolescence was associated with a decline in physical activity (Bradley et al., 2011; Finne et al., 2011). Although trends of decline in physical activity during adolescence are determined by most authors, the association of biological maturation

with physical activity has not been commonly studied (Sherar et al., 2010). It is thought that the effect of changes occurring in adolescent physical activity during maturation may be associated with psychological factors, for instance, body dissatisfaction (Finne et al., 2011). According to the study performed by S. P. Cumming et al. (2010), physical attractiveness perceived by adolescent girls had a close association with the effect of maturation on physical activity. It has been stated that adolescent girls reported having too much fat, and adolescent boys were dissatisfied with their bodies since they perceived themselves as thinner and less muscular (McCabe et al., 2010). Early individual sexual maturation (acceleration) may be linked to overweight resulting from improper diet in childhood (Dunger et al., 2005). Nutrition is an important factor manifesting in children growth and obesity, in addition, it may be linked to early maturation (Dunger et al., 2006).

Swedish researchers (Michaud et al., 2006) determined that a bigger percentage of early maturing girls reported body dissatisfaction and functional disorders. According to the same authors, early or late maturing boys reported higher rates of improper eating habits and depressive symptoms. These conclusions suggest that adolescents and their parents need an appropriate councelling in the field of mental health and health behavior.

Some studies revealed that adolescent body dissatisfaction was associated with health risk behaviors (McCabe et al., 2010), and was one of the factors influencing physical inactivity (Slater, Tiggemann, 2010 a, b). The maturation stage is significant for physical self-assessment and its related behavior. It is determined that early maturing boys who were dissatisfied with their weight more frequently used food supplements that were the predictors for steroid use and disordered eating risk compared with their peers. Early maturing girls who reported body dissatisfaction had weight reducing measures and more frequently consumed food supplements that were the predictors for disordered eating (McCabe, Ricciardelli, 2004). Maturation stages among girls were associated with the traits of self-objectification (focus on the body and body shape), however, such associations among boys were not found (Lindberg et al., 2006).

Although adolescent physical activity is one of the main sources of health (Hallal et al., 2006), schoolchildren's physical activity is insufficient

in our country (Zaborskis, Lenciauskiene, 2006). Thus, the development of programmes for an increase in physical activity among adolescent girls, should be based on the problem of body dissatisfaction. In particular, this problem may be relevant to early maturing adolescents. It is known that early maturing girls experience higher social physique anxiety, and if they are motivated to exercise by body-related reasons, social physical anxiety may contribute to lower levels of physical activity. (Niven et al., 2009). On the other hand, the studies of adolescents aged 12 years reveal that physical activity depends not on the stage of maturation, but on objectified body consciousness (Knowles et al., 2009).

Thus, there is still a lack of studies, particularly, regarding adolescent boys, that investigate the relationships between adolescent sexual maturation, objectified body consciousness, physical activity and eating-related behaviors. The study may contribute to better understanding of associations of adolescent lifestyle with physical activity and weight management, and therefore could be the main focus of the development of preventive health education programmes. The results could assist school specialists of public health and teachers of physical education in adolescent physical activity motivation and/or developing adolescent physical inactivity preventive programmes. **The aim of the study** was to determine the relationships between maturation, physical activity and objectified body consciousness in the sample of adolescents.

RESEARCH METHODS

Design of the study. The study included adolescents from fifteen 9th forms of Kaunas education institutions (4 gymnasiums, 10 secondary schools and one main school). Permission from the Department of Education of Kaunas Municipality was obtained. All headmasters of schools consented to the project. The agreement with every school that participated in the study was signed. The study was approved by Kaunas Committee of Bioethics (Nr. BE-2-62). An survey was carried out by the authors of the study and trained investigators. The interview was performed in the beginning of October, 2010, by receiving an invitation from school. The questionnaires were filled in by schoolchildren with the participation of school public health specialists or class teachers. The school children were informed about anonymity.

This study presents the greater part of the results (the data from the first survey).

The studied sample comprised 293 school children, 57 of them did not fill in questionnaires (because of refusal or absence). Thus the data of 236 students were analyzed. The mean age (SD) of participants was 15 (0.38) years, the youngest was 14, the oldest – 16 years old. The sample consisted of 115 (49%) boys and 121 (51%) girls.

The stage of sexual maturation was determined using Tanner Sexual Maturation Scale, SMS (Marshall, Tanner, 1969; Marshall, Tanner, 1970). For this purpose, the questionnaires to evaluate the subjective stage of sexual maturation were developed individually, for boys and girls. The development of questionnaires was based on the studies performed earlier determining that adolescents might perform self-assessment of sexual maturation (Williams et al., 1988; Matsudo, s. M. M., Matsudo, V. K. R., 1994). Such questionnaires may be used in epidemiological studies when a direct adolescent study to determine maturation stage is impossible (Taylor et al., 2001). One part of the questionnaire had pictures illustrating the secondary sexual characteristics with a description of sexual maturation stage. The studied persons were asked to mark one of the five stages that corresponded best their body status in every description of sexual maturation stage and pictures,. I-II stages corresponded to the beginning of sexual maturation, III–IV – the middle, V – the end.

Objectified body consciousness was determined by the objectified questionnaire (*Self-Objectification Questionnaire,* SOQ; Noll, Fredrickson, 1998). The questionnaire is designed to determine whether an individual assesses his/her body by body-related reasons (e. g. body image), or body functions (e. g. vitality). The participants were asked to rank 10 body characteristics attributing a score from 0 to 9 depending on how a certain characteristic is important for him/her. Five characteristics were attributed to the body functional perception, the other five – to the body assessment as an object. Summing up the characteristics related to body image and functions, two variables are received. The first minus the second is a score of objectified body consciousness which ranges from 25 to –25. The higher the score, the more objectified body consciousness the person has.

Drive for thinness was determined by thinness subscale of the questionnaire (Eating Disorder Inventory-3 (EDI-3; Garner, 2004). It comprises 7 statements with the answers in the four point scale of Likert from "always" (0 or 4 scores) to "never" (0 or 4scores). *Body dissatisfaction* was found using the subscale of body dissatisfaction of the same questionnaire that comprises 10 statements. The number of Lithuanian copies of these scales was obtained from *Psychological Assessment Resources (PAR)*, which holds the copyright for the questionnaire.

Physical activity (rate of exercising). Schoolchildren's exercising rate was determined by the modified leisure time exercise questionnaire (*Leisure Time Exercise Questionnaire,* LTEQ; Godin, Shephard, 1985; Godin, 2011). Respondents were asked to report weekly frequencies of light, moderate and strenuous activities, if the individual exercised longer than 15 minutes. These frequencies were adjusted to metabolic equivalents – 3, 5 and 9, respectively, and later the scores of all intensity levels were summed up. Health-related physical activity may be assessed as strenuous and moderate sum of activities (Godin, 2011), however, in this study we evaluated general physical activity as it was recommended in the initial stage of the design of the questionnaire (Godin, Shephard, 1985). LTEQ instructions comprised the examples of physical activity that were adapted to the common physical activities of adolescents in our country. The questionnaire also contained the second question: "During a typical 7-Day period, in your leisure time, how often do you engage in any regular activity long enough to work up a sweat?" the possible answers: "often", "sometimes", "never/rarely". The study revealed that LTEQ questionnaire was reliable and valid (Jacobs et al., 1993). Average weekly leisure time (excluding lessons) of the sample formed the total of 57 (32.37) scores. The lightest physical activity was 0, and the most strenuous – 259.

Statistical analysis. Statistical data analysis was performed using SPSS 13.0 (*Statistical Package for Social Sciences for Windows)*. The non-parametric Mann-Whitney U and Kruskal-Wallis tests were used to calculate the distribution of mean variables. The Spearman's correlation coefficient rho was applied to calculate correlations between variables. The results were valued as statistically significant if $p < 0.05$.

RESEARCH RESULTS

Normally, the secondary sexual characteristics are becoming more expressed in maturing adolescents aged from 14 to 16 years (the third and fourth stages). The majority of our studied boys and girls reached the fourth stage of sexual maturation, 49.6% and 67.8%, respectively (Table 1). Late maturing adolescents were found only in the boys' group (4.35%). The early maturing adolescents who had the fifth stage of secondary sexual characteristics included 35.7% boys and 14% of girls. Body mass index (BMI) in the sexual maturation stages did not differ. Mean BMI was 20.15, SD = 2.79 kg/m². The lowest BMI was 14.0, the highest – 32.91 kg/m².

Table 1. **Expression of sexual maturation in boys and girls in the sample ($\chi^2 = 22.23$; df = 3; p < 0.001)**

The stage of sexual maturation	Boys (n, %)	Girls (n, %)	Totally in the groups by sexual maturation (n, %)
1	5 (4.3)	0	5 (2.1)
2	–	–	–
3	12 (10.4)	22 (18.2)	34 (14.4)
4	57 (49.6)	82 (67.8)	139 (58.9)
5	41 (35.7)	17 (14.0)	58 (24.6)
Totally in groups by gender (n, %)	115 (100)	121 (100)	236

The mean physical activity was M = 57.63 (32.11) in the group. Physical activity ranged from 0 to 207 points. Boys were physically more active than girls, their score was 65.96 (29.71) and 49.12 (32.39), respectively, Mann-Whitney U = 2602.5; p = 0.0001. Then, the associations of sexual maturation stage with physical adolescent activity were studied. Confident difference was determined in boys between the first and the fifth stages of maturation, Mann-Whitney U = 29.000, p = 0.02 (Table 2). Physical activity in girls did not differ between maturation stages, e. g. comparing the third and the fifth stages, Mann-Whitney U = 63.5, p = 0.291.

The mean score of objectified body consciousness scale in the sample was 9.13 (11.50). The lowest score–25, the highest – 23. Objectified body consciousness was higher in girls compared to boys, 6.49 (12.86) and 11.93 (9.12), respectively,

Mann-Whitney U = 4470; p = 0.003. Objectified body consciousness did not significantly differ only among girls of the third and fourth stages of sexual maturation, Mann-Whitney U = 451; p = 0.01 (Table 3).

Table 2. **Expression of physical activity (SD) in the groups by sexual maturation stages and gender**

The stage of sexual maturation	Boys	Girls
1	7.8 (13.59)	–
3	69.09 (19.26)	48.17 (22.20)
4	69.32 (34.48)	47.51 (34.09)
5	58.33 (25.91)	57.71 (31.70)

Table 3. **Distribution of the mean score of objectified body consciousness scale (SD) in the groups by gender**

The stage of sexual maturation	Boys	Girls
1	−10.20 (7.43)	–
3	−12.85 (8.96)	−13.37 (8.99)
4	−12.85 (9.37)	−4.43 (13.39)
5	−10.69 (8.75)	−8.06 (11. 61)

The mean score of drive for thinness in the sample was 0.8 (1.03). The lowest possible mean score was 0, the highest – 4. Drive for thinness was more expressed in girls than boys 1.07 (1.11) and 0.5 (0.85), respectively, Mann-Whitney U = 3629.5, p = 0.0001 as well as body dissatisfaction: Mann-Whitney U = 4457.50, p = 0.003, respectively. Statistically significant difference of rate of drive for thinness was found in girls who were in the third and fourth, and the third and fifth stages of maturation, Mann-Whitney U = 463, p = 0.009 and Mann-Whitney U = 108, p = 0.05, respectively (Table 4). Body dissatisfaction with an increase of sexual maturation stage showed an increasing trend in both, boys and girls, but the differences were not statistically significant.

We performed the analysis of correlation and determined that sexual maturation in boys slightly correlated with their physical activity (Spearman rho = −0.20, p = 0.048), however, it did not have statistically significant associations with the analyzed variables. Physical activity in girls was not statistically significantly related to the stage of sexual maturation or other analyzed variables.

Table 4. **The mean score of thinness and dissatisfaction scales (SD) in the groups by gender**

The stage of sexual maturation	Boys		Girls	
	Drive for thinness M (SD)	Body dissatisfaction M (SD)	Drive for thinness M (SD)	Body dissatisfaction M (SD)
1	0.17 (0.33)	0.63 (0.48)	–	–
3	0.59 (0.98)	1.11 (1.27)	0.52 (0.69)	1.42 (0.86)
4	0.47 (0.91)	1.16 (1.08)	1.13 (1.05)	1.74 (1.23)
5	0.56 (0.78)	1.54 (1.09)	1.47 (1.50)	1.90 (1.22)

DISCUSSION

This study is a part of larger educational research. In the analysis of primary survey data of the studied sample we aimed at finding out the associations of body perception, physical activity (exercising habits) with the level of sexual maturation in adolescents aged 15 years. The study revealed that higher rates of body dissatisfaction, drive for thinness, objectified body consciousness were linked to sexual maturation level only in later stages suggesting that girls in the fourth and fifth stages of sexual maturation frequently gained more weight, and boys after growth jump sometimes had poorly developed muscles. P. D. Dunkan et. al., (1985) determined that early maturing boys were mostly satisfied with their height and weight. Early maturing girls reported higher rate of dissatisfaction with their weight, and almost 69% of girls wanted to be slimmer. Another study revealed that adolescent girls' perceived body attractiveness was related to sexual maturation and physical activity (Cumming et al., 2011).

In our study, the analysis of associations of sexual maturation stage with physical activity showed a negative relationship in boys. The data of other studies (Sallis, 2000; Gordon-Larsen et al., 2004; Lampert et al., 2007), also showed a decline in physical activity during adolescence. The relationship between girls' sexual maturation and physical activity was not found because of the absence of girls in the first and second sexual maturation stages. On the other hand, the other researchers revealed that physical activity did not depend on maturation stage but on physical self-perception (Knowles et al., 2009).

The study revealed that an increase in sexual maturation increases objectified body consciousness in girls, however, this trend was not found in boys. The same trends were pointed out by other researchers (Lindberg et al., 2006). Girls and boys of higher stages of sexual maturation reported a greater rate of drive for thinness. Similar trends were also found by other authors (McCabe, Ricciardelli, 2004). However, body dissatisfaction, drive for thinness, objectified body consciousness were not associated with adolescent physical activity (exercising rate) in this sample. The further investigations should check this relationship by applying other questionnaires, the monitoring studies would be of great importance as well.

Our study as well as the other research revealed that lower physical activity was common in girls (Zaborskis, Lenciauskiene, 2006; Brunet, Sabiston, 2009; Caglar et al., 2010). According to other researchers, poorer body image is common in girls as well (Brunet et al., 2010; Kerremans et al., 2010; Kerremans et al., 2010).

CONCLUSIONS AND PERSPECTIVES

The study contributes to the research asserting that sexual maturation is associated with lower adolescent physical activity, however, it is common only in boys. Objectified body consciousness in girls and drive for thinness in both genders grow when sexual maturation increases. Rates of body dissatisfaction, drive for thinness, objectified body consciousness are higher in adolescent girls than in boys, however, their exercising rate is lower. Body dissatisfaction, drive for thinness, objectified body consciousness are not related to adolescent physical activity in the sample.

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PAAUGLIŲ LYTINIO SUBRENDIMO IR FIZINIO AKTYVUMO BEI KŪNO SUVOKIMO SĄSAJOS

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Fizinio aktyvumo mažėjimo tendencijos paauglystės laikotarpiu daugelio autorių yra nustatytos, tačiau biologinio brendimo ir fizinio aktyvumo sąsaja dažniausiai netiriama. Manoma, kad brandos pokyčių poveikis paauglių fiziniam aktyvumui gali būti susijęs su psichologiniais veiksniais, pavyzdžiui, nepasitenkinimu savo kūnu.

Tikslas – nustatyti abiejų lyčių paauglių lytinio subrendimo, fizinio aktyvumo ir kūno suvokimo sąsajas.

Metodai. Buvo tiriama penkiolikos Kauno švietimo įstaigų (4 gimnazijų, 10 vidurinių mokyklų ir vienos pagrindinės mokyklos) po vieną devintą klasę. Tiriamąją imtį sudarė 293 moksleiviai, 57 iš jų neužpildė anketų (atsisakė arba apklausos metu nebuvo klasėje). Dėl to toliau buvo analizuoti 236 moksleivių duomenys, iš jų 115 (48,7%) buvo berniukų. Moksleivių amžiaus vidurkis (SD) – 15 (0,38) metų (jauniausiam – 14 m., vyriausiam – 16 m.). Anoniminės apklausos būdu nustatytas paauglių fizinis aktyvumas naudojant Fizinio aktyvumo laisvalaikio metu klausimyną (*Leisure-Time Physical Activity Questionnaire*, LTPAQ; Godin, Shephard, 1985), kūno suvokimas (*Self-Objectification Questionnaire*, SOQ; Noll, Fredrickson, 1998) ir lytinio subrendimo lygmuo naudojant *Tanner* lytinio subrendimo stadijų nustatymo metodą (Marshall, Tanner, 1969; Marshall, Tanner, 1970).

Rezultatai. Vėluojančio brendimo paauglių buvo tik berniukų grupėje. Šiek tiek daugiau nei trečdalis berniukų ir beveik penktadalis mergaičių bręsta anksčiau. Tiriant sąsajas tarp lytinio subrendimo stadijos ir moksleivių fizinio aktyvumo, aptiktas neigiamas ryšys berniukų grupėje. Tyrimas atskleidė, kad vis labiau lytiškai subręstant didėja mergaičių sudaiktintas kūno suvokimas, tačiau tarp berniukų ši tendencija nenustatyta. Vis labiau mergaitėms ir berniukams lytiškai subręstant, didėja liesumo siekimas. Mergaičių nepasitenkinimas savo kūnu, liesumo siekimas, sudaiktintas kūno suvokimas yra didesnis negu berniukų, tačiau mankštinimosi dažnis yra mažesnis. Nepasitenkinimas savo kūnu, liesumo siekimas, sudaiktintas kūno suvokimas nebuvo susijęs su paauglių fiziniu aktyvumu tiriant šią imtį.

Aptarimas ir išvados. Tyrimas prisideda prie studijų, kurios teigia, kad lytinis subrendimas susijęs su mažesniu paauglių fiziniu aktyvumu, tačiau tai pastebima tik tarp berniukų. Vis labiau lytiškai subręstant, didėja mergaičių sudaiktintas kūno suvokimas ir abiejų lyčių paauglių liesumo siekimas. Nepasitenkinimas savo kūnu, liesumo siekimas, sudaiktintas kūno suvokimas nebuvo susijęs su paauglių fiziniu aktyvumu tiriant šią imtį.

Raktažodžiai: brendimas, fizinis aktyvumas, kūno suvokimas.

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

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3. Requirements for the preparation of manuscripts

3.1. Manuscripts must be typed on white standard A4 paper (210×297 mm) with the interval between lines 6 mm (1.5 line spaced), with a character size at 12 points, with 3 cm margin on the left and 1.5 cm on the right, with a 2.5 cm margins at the top and the bottom of the page. Pages are numbered in the bottom right-hand corner beginning with the title page numbered as Page 1.

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3.3. The title page should contain: a) a short and informative title of the article (no more than 80 characters without spaces); 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 was done; d) the name, address, phone 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.

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

McDonald, C., Chenoweth, L. (2009). Leadership: A crucial ingredient in unstable times. *Social Work & Society, 7* [04 08 2006]. Internet link: http://www.socwork.net/2009/1/articles/mcdonaldchenoweth

Ratkevičius, A., Skurvydas, A., Lexell, J. (1995). Submaximal exercise-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 Training and Competition.* Champaign, Illinois: Human Kinetics.

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