UGDYMAS
KŪNO KULTŪRA
sportas

Education
Physical Training
Sport

LKKA

Lietuvos
kūno kultūros akademija

Lithuanian Academy
of Physical Education

3
2011

Žurnale „UGDYMAS • KŪNO KULTŪRA • SPORTAS“ spausdinami originalūs ir apžvalginiai šių mokslo krypčių (šakų) straipsniai:

- *Socialiniai mokslai* (fizinis ugdymas, treniravimo sistemos, sporto pedagogika, sporto psichologija, sporto sociologija, sporto mokslo metodologija, sporto vadyba, rekreacija ir turizmas).
- *Biomedicinos mokslai* (sporto fiziologija, judesių valdymas ir mokymasis, sporto biochemija, sporto medicina, kineziterapija ir ergoterapija, fizinis aktyvumas ir sveikata, sporto biomechanika, taikomoji fizinė veikla).
- *Humanitariniai mokslai* (sporto istorija, sporto filosofija, sporto teisė, sporto terminologija).

Įtrauktas į Cenral and Eastern European Academic Source (EBSCO sąrašas), IndexCopernicus, SPORTDiscus with Full Text (EBSCO sąrašas) duomenų bazes.

Šiame numeryje spausdinami socialinių ir biomedicinos mokslų straipsniai.

— • —

The journal publishes original and review papers in the following areas:

- *Social Sciences* (Physical Education, Sports Coaching, Sports Pedagogy, Sports Psychology, Sports Sociology, Research Methods in Sports, Sports Management, Recreation and Tourism).
- *Biomedical Sciences* (Sports Physiology; Motor Control and Learning, Sports Biochemistry, Sports Medicine, Physiotherapy and Occupational Therapy, Physical Activity and Health, Sports Biomechanics, Adapted Physical Activity.
- *Humanities* (Sports History, Sports Philosophy; Sports Law, Sports Terminology).

Indexed in Central and Eastern European Academic Source (EBSCO), IndexCopernicus, SPORTDiscus with Full Text (EBSCO).

Research articles in Social and Biomedical Sciences are given in this issue.

LIETUVOS KŪNO KULTŪROS AKADEMIJA

UGDYMAS•KŪNO KULTŪRA•SPORTAS

3 (82)

2011

ISSN 1392–5644

Žurnalas „Ugdymas. Kūno kultūra. Sportas“ leidžiamas nuo 1968 m.

(ankstesnis pavadinimas – mokslo darbai „Kūno kultūra“)

Viršelio dailininkas Gediminas Pempė
Redaktorės V. Jakutienė ir dr. D. Karanauskienė

Leidžia **LIETUVOS KŪNO KULTŪROS AKADEMIJA**
Sporto g. 6, LT-44221 Kaunas
Tel. +370 37 302636
Faks. +370 37 204515
Elektr. paštas zurnalas@lkka.lt
Interneto svetainė www.lkka.lt/lt/zurnalas

10 sp. l. Tiražas 150 egz. Užsakymas 686.
Spausdino leidyklos „Technologija“ spaustuvė, Studentų g. 54, LT-51424 Kaunas

TURINYS

LITHUANIAN ACADEMY OF PHYSICAL EDUCATION

EDUCATION•PHYSICAL TRAINING•SPORT

3 (82)

2011

ISSN 1392–5644

Journal „Education. Physical Training. Sport“ has been published since 1968
(the former title — selected papers „Kūno kultūra“ /Physical Training/)

The cover has been designed by Gediminas Pempė
Editors V. Jakutienė and Dr. D. Karanauskienė

Published by
LITHUANIAN ACADEMY OF PHYSICAL EDUCATION

Sporto str. 6, LT-44221 Kaunas, Lithuania
Phone +370 37 302636
Fax +370 37 204515
E-mail zurnalas@lkka.lt
Home page www.lkka.lt/en/zurnalas

CONTENTS

BONE MINERAL DENSITY AND JUMPING HEIGHT IN PRE-MENARCHEAL AND POST-MENARCHEAL PHYSICALLY ACTIVE GIRLS

Rita Gruodytė[1, 2], Toivo Jürimäe[3]
Lithuanian Academy of Physical Education[1], Kaunas, Lithuania
University of Saskatchewan[2], Saskatchewan, Canada
University of Tartu[3], Tartu, Estonia

ABSTRACT

Research background and hypothesis. Jumping ability correlates well with different bone values. The skeletal benefits of high-impact weight-bearing exercise have been shown to be greater when training is started prior to menarche. We hypothesized that significant differences would be apparent in the relationships between bone values and jumping height in favor of the girls' prior menarche compared to post-menarcheal group.

Research aim. The aim of the study was to investigate the relationships between jumping height and bone mineral density (BMD) in pre-menarcheal and post-menarcheal physically active girls.

Research methods. In total, 113 adolescent girls from different competitive extramural athletic programs participated in this study. Femoral neck and lumbar spine BMD were measured. The heights of vertical jumps (i. e. countermovement jump (CMJ) and rebound jumps for 15 (RJ 15 s) and 30 (RJ 30 s) seconds) were obtained.

Research results. After adjusting for major confounders (i. e. age, height, and body mass), the height of rebound jumps correlated only with femoral neck BMD and only in pre-menarcheal group ($r = 0.37–0.46$; $p < 0.05$). No correlations were found between BMD variables and jumping height in post-menarcheal girls. The height of CMJ did not correlate with measured BMD variables in the studied groups.

Discussion and conclusions. Early puberty is an opportune period to increase bone adaptation to mechanical loading due to the velocity of bone growth and endocrine changes at this time. We suggest that powerful repetitive vertical jumping may be more beneficial to bone health compared to single jumping activities in physically active girls prior to menarche rather than after it.

Keywords: bone health, vertical jumps, puberty.

INTRODUCTION

Regular high-impact weight-bearing physical activity (such as ball games, racket sports, gymnastics, dance, running, or jumping exercises) during growth may play an important role in maximizing bone mineral mass gain which may reduce the incidence of fractures in children and adolescents as well as in the elderly (Misra, 2008; Rizzoli et al., 2010). Early puberty is a period for increased bone adaptation to mechanical loading due to the velocity of bone growth and endocrine changes at this time (Hind, Burrows, 2007). The two critical years for accumulating more than 25% of adult bone in girls correspond to the ages 11.5–13.5 (MacKelvie et al., 2002). The skeletal benefits of exercise have been shown to be greater when training is started prior to menarche (Heinonen et al., 2000). Of different exercise modalities, high-impact activity, for example, jumping, seems to be especially osteogenic (MacKelvie et al., 2002). Several studies have reported high-impact jumping exercise interventions to be an effective bone stimulus in females at pre-puberty, adolescence or young adulthood (MacKelvie et al., 2003; Kato et al., 2006; Gunter et al., 2008). Jumping ability seems to correlate well with different bone values: different vertical jumps have been used to evaluate jumping ability in young athletes (Kellis et al., 1999). In our previous study (Gruodytė et al., 2009) we attempted to investigate the relationships between bone mineral values and jumping ability in pubertal girls in relation to the different loading patterns of their selected sports. The main finding of the study was that jumping height correlated with bone variables in girls who experienced continuous high-impact physical activity, such as sport games and rhythmic gymnastics (Gruodytė et al., 2009). However, little is known about the possible relationships between maximal vertical jumping height and bone parameters in adolescent female athletes with regard to the menarche.

The aim of the current study was to evaluate the relationships of BMD at femoral neck and lumbar spine with jumping height of single maximal jump and repetitive rebound jumps for 15 and 30 seconds in physically active girls in relation to menarche. Would the significant differences be apparent in pre- and post-menarcheal groups in regard to the relationships between bone values and jumping height? We hypothesized that it should be – in favor of the girls' prior menarche compared to post-menarcheal group.

RESEARCH METHODS

In total, 113 healthy 13–15-year-old physically active girls participated in this cross-sectional study. The girls were recruited from national sport associations and local clubs in Estonia. The volunteers participated in the selected competitive extramural athletic programs (such as gymnastics, volleyball, basketball, badminton, track and field sprint) at least for two years. The study subjects were divided in pre-menarcheal (n = 36) and post-menarcheal (n = 77) groups. A full written description of the nature of the study was provided both to the girls and their parents before obtaining their informed written consent. The study was approved by the Medical Ethics Committee of the University of Tartu (Estonia).

Height and body mass were measured to the nearest 0.1 cm and 0.05 kg respectively, using the Martin's metal anthropometer and medical scales (*A&D Instruments Ltd*, UK). Body mass index (BMI) (kg/m^2) was calculated using height and body mass data. A simple questionnaire was used to obtain the information about the onset of the training and weekly hours of participating in weight-bearing physical activities. The girls were also asked if they had experienced menarche. If positive, they were asked to recall the age when menarche occurred. Gynecological age (years) was calculated subtracting the athlete's self-reported age at menarche from her chronological age (Barkai et al., 2007).

Bone mineral density (g/cm^2) at lumbar spine (L2–L4) and femoral neck were measured using dual-energy X-ray absorptiometry (DXA; DPX-IQ, *Lunar Corporation*, Madison, WI, USA). Participants were scanned in light clothing while lying flat on their backs with arms at their sides. DXA measurements and results were evaluated by the same examiner. Coefficients of variations for BMD measurements were less than 2%.

The maximal height of two-foot hands-on-the-hips vertical jumps was measured using contact mat (*Newtest OY*, Finland) which was connected to a digital recorder that calculated the flight height. The girls have performed three jumping tests in the following order: (1) a countermovement jump (CMJ) from a standing position with a preliminary countermovement; (2) the rebound jump, with continuous countermovement jumps for 15 seconds (RJ 15 s); and (3) the rebound jump for 30 seconds (RJ 30 s) (Kellis et al., 1999). In CMJ, the best result out of three attempts was recorded. The girls were instructed and then verbally encouraged to jump as high and as rapidly as they could. The hands remained on waist throughout all jumping tests to avoid upper extremities contribution to the jump height (Kellis et al., 1999). Each subject performed RJ 15 s test immediately after CMJ test; and RJ 30 s test after a sufficient rest period (i. e. after another subject had performed CMJ and RJ 15 s tests).

Statistical analysis was carried out using *SPSS 15.0* package for *Windows*. Standard statistical methods were used to calculate means and standard deviations (± SD). A one-way analysis of variance (ANOVA) was used to establish the differences between the groups. Pearson's correlation coefficients were computed to identify relationships between jumping performance and BMD variables. Partial correlation analysis was used to examine this relationship after controlling for major confounders (i. e. age, body height, and body mass). A significance level of 0.05 was used.

RESEARCH RESULTS

The physical and performance characteristics of the study subjects are presented in Table 1. The significant differences between the two groups were found in age, height, body mass, BMI, amount of the weekly hours of training, and BMD variables. The results of jumping tests did not differ significantly between the groups of pre-menarcheal and post-menarcheal girls (Table 1).

The significant correlations ($r = 0.33–0.48$; $p < 0.05$) were revealed between BMD variables and rebound jumps in pre-menarcheal girls (Table 2). After the adjustments for age, height, and body mass were performed, the significant relationships of rebound jumps were found only with BMD at femoral neck in pre-menarcheal girls only. The relationships between BMD variables and CMJ were not significant ($p > 0.05$). No significant associations between measured BMD variables and jumping test results were found in post-menarcheal group of physically active girls.

DISCUSSION

Although there have been numerous interventions, implementing jumping exercise to augment bone health, there is a dearth of data quantifying the relationships between jumping height and bone values. The results of present cross-sectional investigation demonstrated that BMD at femoral neck and lumbar spine significantly correlated with rebound jumps for 15 and 30 seconds in physically active girls only from the pre-menarcheal group. The relationships remained significant between BMD at femoral neck and rebound jumps after controlling for age, height, and body mass, suggesting that BMD at femoral neck is more sensitive to the mechanical loading and weight-bearing physical activity than lumbar spine, and it was observed in pre-menarcheal but not in post-menarcheal girls. This could be explained by the fact that skeletal response to the weight-bearing exercise is site-specific. Numerous

Table 1. **Mean (± SD) physical and performance characteristics of the study subjects**

Physical and performance characteristics	Pre-menarcheal girls (n = 36)	Post-menarcheal girls (n = 77)
Age, years	13.6 ± 0.9	14.4 ± 0.9**
Height, cm	163.1 ± 7.7	167.7 ± 6.7*
Body mass, kg	49.7 ± 7.7	57.8 ± 8.6**
BMI, kg/m^2	18.6 ± 2.2	20.5 ± 2.5**
Gynecological age, years	–	1.9 ± 1.0
Years of training	4.6 ± 2.3	4.5 ± 2.0
Training duration, h/w	7.3 ± 4.2	5.4 ± 2.4*
Femoral neck BMD, g/cm^2	1.004 ± 0.132	1.091 ± 0.109**
Lumbar spine BMD, g/cm^2	1.021 ± 0.117	1.151 ± 0.110**
CMJ, cm	27.6 ± 3.5	26.2 ± 4.1
RJ 15 s, cm	23.2 ± 3.4	22.4 ± 3.4
RJ 30 s, cm	22.3 ± 3.5	21.6 ± 3.4

Note. BMI – body mass index; BMD – bone mineral density; CMJ – countermovement jump; RJ 15 s – the rebound jump for 15 seconds; RJ 30 s – the rebound jump for 30 seconds. Significant differences between the groups are indicated with asterix: * – $p < 0.01$; ** – $p < 0.001$.

Table 2. **Pearson's correlation for BMD variables and jumping height in pre-menarcheal and post-menarcheal girls. Partial correlation analysis (controlled for age, height, and body mass) is presented in brackets**

BMD variables	Pre-menarcheal girls (n = 36)	Post-menarcheal girls (n = 77)
Femoral neck BMD, g/cm^2		
CMJ, cm	0.04 (0.02)	0.13 (0.20)
RJ 15 s, cm	0.48** (0.46**)	0.12 (0.22)
RJ 30 s, cm	0.43** (0.37*)	0.08 (0.22)
Lumbar spine BMD, g/cm^2		
CMJ, cm	0.13 (0.21)	0.09 (0.15)
RJ15 s, cm	0.33* (0.32)	0.11 (0.19)
RJ30 s, cm	0.34* (0.29)	0.14 (0.24)

Note. BMD – bone mineral density; CMJ – countermovement jump; RJ 15 s – rebound jump for 15 seconds; RJ 30 s – rebound jump for 30 seconds. Significant differences between the groups indicated with asterix: * – $p < 0.05$; ** – $p < 0.01$.

physical activity intervention trials, aiming to increase BMD, report the most significant effects at the femoral neck, because they include different jumping exercises that generate impact forces through the lower limbs, hence creating a greater loading at the hip than at the spine (Hind, Burrows, 2007). On the other hand, exercise seems to be more beneficial for additional bone mineral acquisition before menarche (i. e. during the growth spurt) rather than after it, which may be due to the increase of estrogen and free, biologically active insulin-like growth factor-1 (IGF-1) levels occuring between the ages 11.5–13.5, corresponding to the timing of menarche and peak bone mineral accrual velocity (MacKelvie et al., 2002). The results of a 9-month exercise intervention study by A. Heinonen et al. (2000) indicated that mechanical loading exercise intervention had significantly greater impact on bone mineral content (BMC) increase at lumbar spine and femoral neck in exercising premenarcheal girls compared to exercising postmenarcheal girls or controls. Despite the fact that increase in bone mineral in the growing girls may be attributable to growth itself, A. Heinonen et al. (2000) study reported significant additional bone gain after the intervention in premenarcheal girls only. In contrast, H. S. Barkai and colleagues (2007), in a study of 13–18-year-old girls participating in structured weight-bearing sports, found the strongest associations of the amount of weight-bearing exercise with BMD at the spine, hip, and total body in postmenarcheal group. Nevertheless, these results must be interpreted cautiously, since almost a third of the study population reported having no structured sports participation before menarche (Barkai et al., 2007). Menstrual history is a strong predictor of bone mineral density: delayed menarche may cause lower peak bone mass attainment or may be a marker for other possible influences on stress fracture risk such as low body fat, low body weight, future menstrual disturbance, or excessive training (Pepper, Saint-Phard, 2007). In contrast to the regular weight-bearing physical activity, excessive training may have a negative impact on bone health. Girls and women participating in sports very intensively, and especially in those that emphasize a low body weight (such as gymnastics, running, or ballet) are more likely than other active women to expose themselves to the detrimental condition named the female athlete triad (i. e. disordered eating, menstrual dysfunction, and low bone density) (Manore et al., 2007).

Maximum vertical jump performed from the standing position with a countermovement (CMJ) as well as rebound jumps for 15 (RJ 15 s) and 30 (RJ 30 s) seconds reflect well jumping abilities in young athletes (Kellis et al., 1999). In turn, jumping height may be influenced by different factors, such as muscle fibre type composition, lean body mass, muscular strength, age, anthropometric parameters and/or angle of the legs bent in knee joints at the take off (Jürimäe et al., 2008). It is well known that the power of jumping is higher in subjects rich in fast-twitch muscle fibers than in subjects with high percentage of slow-twitch muscle fibers (Bosco et al., 1986). B. Buehring et al. (2010) found that jump power is higher in younger (20–30 years of age) comparing to older (60+) populations. Their study also found that jump height and power were positively correlated with percent lean mass at the hip. Many of these factors were not taken into account in our study. Nevertheless, the present investigation provides some significant insights in the area of bone mineral density relationships with the jumping height in adolescent female athletes with regard to menarche. It is interesting to note, that in the present study CMJ did not correlate with measured BMD variables in the studied girls. Similar trends were revealed in our previous study of pubertal girls with different physical activity patterns (Gruodytė et al., 2009). Another study has also demonstrated that single vertical jumping height was not among the signicant predictors of legs BMD in prepubertal children (Jürimäe et al., 2008). Accordingly, these results suggest that continuous high-impact activities are more important to bone health compared to single jumping activities in physically active premenarcheal girls.

CONCLUSIONS AND PERSPECTIVES

In conclusion we may suggest that powerful repetitive vertical jumping may be more beneficial to bone health in physically active girls prior to menarche rather than after it. Significant associations after adjusting for age, height, and body mass were found between BMD at femoral neck and rebound jumps for 15 and 30 seconds in pre-menarcheal, but not in post-menarcheal physically active girls.

REFERENCES

Barkai, H. S., Nichols, J. F., Rauh, M. J. et al. (2007). Influence of sports participation and menarche on bone mineral density of female high school athletes. *The Journal of Science and Medicine in Sport*, 10, 170–179.

Bosco, C., Tihanyi, J., Latteri, F. et al. (1986). The effect of fatigue on store and re-use of elastic energy in slow and fast types of human skeletal muscle. *Acta Physiologica Scandinavica*, 128 (1), 109–117.

Buehring, B., Krueger, D., Binkley, N. (2010). Jumping mechanography: A potential tool for sarcopenia evaluation in older individuals. *Journal of Clinical Densitometry: Assessment of Skeletal Health*, 13 (3), 283–291.

Gruodytė, R., Jürimäe, J., Saar, M. et al. (2009). Relationships between areal bone mineral density and jumping height in pubertal girls with different physical activity patterns. *The Journal of Sports Medicine and Physical Fitness*, 49 (4), 474–479.

Gunter, K., Baxter-Jones, A. D. G., Mirwald, R. L. et al. (2008). Impact exercise increases BMC during growth: An 8-year longitudinal study. *Journal of Bone and Mineral Research*, 23 (7), 986–993.

Heinonen, A., Sievinen, H., Kannus, P. et al. (2000). High impact exercise and bones of growing girls: A 9-month controlled trial. *Osteoporosis International*, 11, 1010–1017.

Hind, K., Burrows, M. (2007). Weight-bearing exercise and bone mineral accrual in children and adolescents: A review of controlled trials. *Bone*, 40, 14–27.

Jürimäe, T., Hurbo, T., Jürimäe, J. (2008). Relationships between legs bone mineral density, anthropometry and jumping height in prepubertal children. *Collegium Antropologicum*, 32 (1), 61–66.

Kato, T., Terashima, T., Yamashita, T. et al. (2006). Effect of low-repetition jump training on bone mineral density in young women. *Journal of Applied Physiology*, 100, 839–843.

Kellis, S. E., Tsitskaris, G. K., Nikopoulou, M. D., Mousikou, K. C. (1999). The evaluation of jumping ability of male and female basketball players according to their chronological age and major leagues. *The Journal of Strength and Conditioning Research*, 13, 40–46.

MacKelvie, K. J., Khan, K. M., McKay, H. A. (2002). Is there a critical period for bone response to weight-bearing exercise in children and adolescents? A systematic review. *British Journal of Sports Medicine,* 36, 250–257.

MacKelvie, K. J., Khan, K. M., Petit, M. A., Janssen, P. A., MacKay, H. A. (2003). A school-based exercise intervention elicits substantial bone health benefits: A 2-year randomized controlled trial in girls. *Pediatrics*, 112 (6), e447–452.

Manore, M. M., Kam, L. C., Loucks, A. B. (2007). The female athlete triad: Components, nutrition issues, and health consequences. *The Journal of Sports Sciences*, 25, S 61–71.

Misra, M. (2008). Bone density in the adolescent athlete. *Reviews in Endocrine & Metabolic Disorders*, 9, 139–144.

Pepper, M., Saint-Phard, D. (2007). Bone health concerns in active and athletic women and girls. *Orthopedics*, 30 (4), 281–287.

Rizzoli, R., Bianchi, M. L., Garabedian, M. et al. (2010). Maximizing bone mineral mass gain during growth for the prevention of fractures in the adolescents and the elderly. *Bone*, 46, 294–305.

SPORTUOJANČIŲ MERGAIČIŲ KAULŲ MINERALINIO TANKIO IR ŠUOLIŲ AUKŠČIO SĄSAJOS MENARCHĖS POŽIŪRIU

Rita Gruodytė[1, 2], Toivo Jürimäe[3]
Lietuvos kūno kultūros akademija[1], Kaunas, Lietuva
Saskačevano universitetas[2], Saskačevanas, Kanada
Tartu universitetas[3], Tartu, Estija

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Šoklumo ypatybės ir kaulų sveikatos rodikliai yra tarpusavyje susiję. Teigiamas reguliarios mechaninės griaučių apkrovos poveikis yra didesnis, kai sportuoti pradedama iki prasidedant menarchei. Tyrimu tikrinama hipotezė, kad sąsajos tarp šoklumo ir kaulų sveikatos rodiklių labiau pasireiškia tarp sportuojančių mergaičių, dar nepatyrusių menarchės.

Tikslas: nustatyti pubertetinio amžiaus fiziškai aktyvių mergaičių kaulų mineralinio tankio (KMT) ir šoklumo rodiklių sąsajų priklausomumą nuo menarchės.

Metodai. Buvo tiriama 113 sveikų 13–15 m. amžiaus mergaičių, reguliariai lankiusių gimnastikos, badmintono, rankinio, krepšinio, lengvosios atletikos (trumpųjų nuotolių bėgimo) ir lygumų slidinėjimo pratybas. Atsižvelgiant į tai, ar mergaitės jau buvo patyrusios pirmąsias mėnesines, buvo sudarytos dvi grupės: iki ir po menarchės (n = 36 ir 77 atitinkamai). Nustatytas šlaunikaulio kaklelio ir juosmeninės stuburo dalies KMT. Išmatuoti tiriamųjų šoklumo (maksimalaus vertikalaus šuolio, 15 ir 30 sekundžių trukmės maksimalių vertikalių šuolių serijos (cm)) rodikliai.

Rezultatai. Atmetus pagrindinių KMT lemiančių veiksnių (t. y. amžiaus, ūgio ir kūno masės) poveikį, statistiškai reikšmingi koreliaciniai ryšiai nustatyti tik tarp šlaunikaulio kaklelio KMT ir šuolių aukščio 15 bei 30 sekundžių trukmės maksimalių vertikalių šuolių serijų metu tarp fiziškai aktyvių mergaičių, nepatyrusių menarchės ($r = 0{,}37$–$0{,}46$; $p < 0{,}05$). Tarp KMT ir šoklumo rodiklių menarchę patyrusiųjų grupėje, tarp KMT ir maksimalaus vertikalaus šuolio aukščio abiejose grupėse nustatyti statistiškai nereikšmingi koreliaciniai ryšiai ($p > 0{,}05$).

Aptarimas ir išvados. Išanalizavus tyrimo rezultatus galima teigti, kad mechaninė griaučių apkrova (pvz., 15 ir 30 sekundžių trukmės maksimalių vertikalių šuolių serijos) gali teigiamiau veikti reguliariai sportuojančių paauglių mergaičių kaulų masę iki prasidedant menarchei nei po jos

Raktažodžiai: kaulų sveikata, vertikalūs šuoliai, paauglystė.

Gauta 2010 m. kovo 16 d.
Received on March 16, 2010

Priimta 2011 m. birželio 16 d.
Accepted on June 16, 2011

Corresponding author **Rita Gruodytė**
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 37 302669
E-mail r.gruodyte@lkka.lt

EFFECT OF CORE STABILITY EXERCISE ON CROSS-SECTIONAL AREA OF LUMBAR MULTIFIDUS MUSCLE AND PHYSICAL CAPACITY

Irina Klizienė[1], Saulė Sipavičienė[2], Daiva Imbrasienė[2], Šarūnas Klizas[2], Hermanas Inokaitis[2]
Kaunas University of Technology[1], Kaunas, Lithuania,
Lithuanian Academy of Physical Education[2], Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Our research novelty was the validation of the use of the method of Ultrasound Imaging to measure the changes in the size of the cross-sectional area (CSA) of the multifidus muscle, performing exercises for lumbar stability. Stabilization exercises have been designed in order to enhance the neuromuscular control system correct the dysfunction.

Research aim. The purpose of this study was to establish the effect of core stability exercise for cross-sectional area of lumbar multifidus muscle and physical capacity for elderly women.

Research methods. The elderly women (n = 22) were in occupations involving light or no manual work and did not take part in sports. CSA of the multifidus muscle was measured from L2 to L5 vertebral segments. These measures were taken with ultrasound „TITAN™" (*SonoSite*, USA). For the assessment of physical capacity we estimated the women's static strength endurance of back muscles and dynamic strength endurance of abdominal muscles. The tests were done three times: the first testing occurred before exercises for training lumbar stability, the second – after four months, and the third – after eight months of applying exercises for training lumbar stability.

Research results. The results of study showed that after eight months of stability exercises, the subjects had significantly larger right side multifidus CSA than before practice – 9.01 ± 1.1, the left side of the lumbar multifidus muscle was 8.23 ± 0.9 ($p < 0.05$). After the evaluation of physical capacity we revealed that after eight moths it was 97.6 ± 2.8 s (very good), compared to the values before the research (25.4 ± 9.2) ($p < 0.05$).

Discussion and conclusions. After the core stabilization exercise program multifidus CSA values were significantly larger than before practice, multifidus muscle asymmetry decreased. Physical activity programs adapted to the elderly women increased their physical capacities.

Keywords: lumbar stability, physical activity programs, age.

INTRODUCTION

Exercises are frequently used by physical therapists for the treatment of low back pain. Specific exercises that activate *abdominal* and/or back *extensor* muscles are advocated to reduce pain and disability (Richardson et al., 1999; McGill, 2002). Low back pain is a major problem involving high sport medical costs; therefore effective prevention strategies are essential. Much discussion exists about which is the most effective technique to improve spine stability (Vera-Garcia et al., 2007). The role of exercise and activity in the management of back pain has changed markedly over the last century. Core stability exercise may provide several benefits to the musculoskeletal system, from maintaining low back health to preventing and increasing the cross-sectional area

(CSA) of *lumbar multifidus* muscle. Stabilization exercises have been designed in order to enhance the neuromuscular control system and correct the dysfunction. The general conclusion is that exercises are ineffective for acute low back pain or as effective as other treatments, but they are effective for chronic low back pain or even more effective than other treatment. However, there is limited evidence for specific rather than general exercises (Norris, 2000; Stokes et al., 2005). J. A. Hayden (2005) and colleagues performed a meta-analysis looking at exercise intervention types and their effects on pain and disability and concluded that exercise therapy consisting of individually designed programmes, including stretching or strengthening, stabilization exercises delivered with supervision might improve pain reduction in chronic non-specific low-back pain (Hayden et al., 2005).

Several studies examined *multifidus muscle* size among asymptomatic, healthy persons. Ultrasound Imaging was validated as a noninvasive method to measure the activation of selected muscles (Kiesel et al., 2007). A study of healthy young females using Ultrasound Imaging and Magnetic Resonance Imaging showed that the *multifidus* was symmetrical between sides at each vertebral level studied (L2–S1) and increased incrementally in size from L2 to L5 (MacDonald et al., 2006). Fifty-one normal subjects were measured using real-time ultrasound imaging at the L4 vertebral level, and in 10 subjects the measurements were made at each vertebral level from L2-S1. A recent study of 120 asymptomatic subjects provided reference ranges for the *lumbar multifidus* at the L4 and L5 vertebral levels across various age ranges using real-time Ultrasound Imaging (Hides et al., 1995). Results showed that lumbar *multifidus* CSA was larger in males, and age had no effect on *multifidus* muscle size. In agreement with the previous studies, between-side symmetry was high for lumbar *multifidus* muscle size (CSA 10% between – side differences).

Elderly aging is accompanied by several morphological, physiological and biochemical alterations. Among these alterations, muscular strength, flexibility, balance and physical conditioning deficits can be highlighted (Zhong et al., 2007). The flexibility loss in the elderly people changes the walking pattern in relation to the step's amplitude and the balance, harming the functional independence and increasing the risk of falls (Fraga et al., 2011). With aging the nervous system presents neuronal loss and a decrease in the nervous conduction velocity, a fact that compromises the good behavior of the systems responsible for the postural control (Jankelowitz et al., 2007). The VO_2max presents a reduction of 0.4–0.5 ml/(kg/min) in each year of sedentary women's life, representing a loss of 50% from the thirties to the eighties (Hagberg, 1989). Physical activity programs adapted to elderly people have been implemented in Lithuania with the intention of minimizing the alterations provoked by aging. Several studies demonstrated the efficacy of these programs in the improvement or maintenance of muscular strength, flexibility, balance, physical conditioning and body weight (Hauer et al., 2006).

In Lithuania the diagnostic method of Ultrasound Imaging has not been widely used for the measurement of changes in the size of the cross-sectional area of the multifidus muscle or for obtaining feedback in the rehabilitation of lumbar pain performing exercises meant for lumbar stability as well as establishing indices of physical development and physical capacity. Thus, there is not much research on those issues. The purpose of this study was to establish the effect of core stability exercise for cross-sectional area of lumbar *multifidus muscle* and physical capacity for elderly women.

RESEARCH METHODS

The subjects were either sedentary or moderately active females. The elderly women (n = 22) were in occupations involving light or no manual work and did not take part in sports. Their age was 64.8 ± 5.4 years, body weight – 67.6 ± 4.2 kg, height – 165.7 ± 8.9 cm, and body fat – 28.9 ± 11.3% (body fat mass – 19.6 ± 9.1 kg). Each subject read and signed a written informed consent form consistent with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from Kaunas Regional Biomedical Research Ethics Committee (Report Number BE-2-24).

Testing and assessment of multifidus muscle CSA. CSA of the multifidus muscle was measured from L2 to L5 vertebral segments with ultrasound „TITAN™" (*SonoSite*, *USA*). The resultant image was displayed on the screen (Figure 1) from which multifidus CSA were determined using electronic calipers. This process was repeated for each subsequent vertebral segment. Bilateral images of the multifidus muscles were obtained where possible except for the cases of larger subjects where left and right sides were imaged separately (Hides et al., 2008 a) (Figure 1). The subjects were

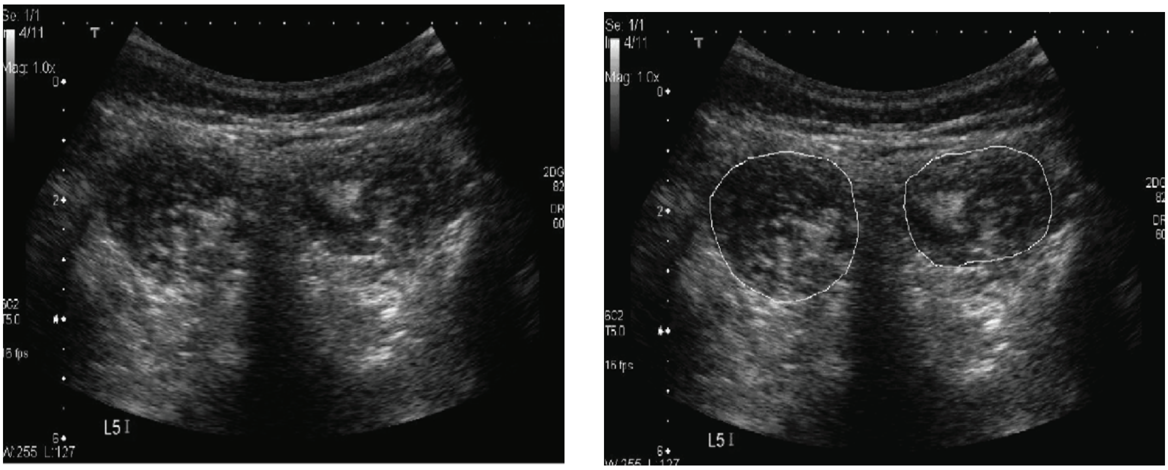


Figure 1. **Bilateral transverse image at the L5 vertebral level showing atrophy of the right lumbar multifidus muscle, with and without CSA tracings (Hides et al., 2008 a)**

instructed to relax their paraspinal musculature, electro conductive gel was applied, and the transducer placed transversely over the spinous process of the vertebral level which was measured. This produced images in which the spinous process and laminate could be seen, with multifidus muscles visible on both sides of the spine. The CSA of the multifidus was measured by tracing around the muscle border with the on-screen cursor. The CSA of the multifidus muscle percentage expression of symmetry was calculated following the recommendations in research literature.

Physical capacity. *Keeping the trunk in the horizontal position with the face down.* This test was used to evaluate the static strength endurance of back muscles. The subject had to lie on a gymnastic bench so that her pelvic bones protruded over the edge of the bench, hands on the floor, and then the partner held the legs tight on the bench. After the start signal the subject had to clasp hands behind neck and keep the trunk in a horizontal position. We registered how much time the subject was able to keep the body in a horizontal position. The evaluation of females was as follows: very good – 86 s and more, good – 71–85 s, moderate – 41–70 s, worse that moderate – 26–40 s, poor – 25 s and less (Volbekienė, 2003).

For the evaluation of the *dynamic strength endurance of abdominal muscles* we applied the "sit up" test. The subject lied on the floor with legs bent at the angle of 90^0 and hands clasped behind the neck, the partner held the feet. The test lasted for 30 s (the subjects had to perform as many sit ups as they could without resting) (Volbekienė, 2003).

Exercises in the testing procedure. Six exercises (often used in clinical practice to train lumbar stability) were performed. The group of exercises was executed in supine position, knees bent (60° flexion) and feet on the floor. The following exercises was performed in four-point kneeling. At the start of each exercise, the examiner determined the subject's lumbar neutral spine position and the subjects were asked to hold this position throughout the exercise. The exercises were performed in a random sequence. In order to standardize the position of the subject and the equipment, markers were placed on the floor. The dynamic phases (i. e. lifting and lowering of the pelvis and the extremities) lasted for 2 s. The midphase (i. e. extended leg/arm and lifted pelvis) was held for 5 s. The rhythm of 60 beats/min was set by a metronome. For each exercise three trials were performed. To prevent muscular fatigue, an interval of at least 15 s was allowed between the exercises; during these periods the exercises were explained. At the start of each exercise, the examiner determined the subject's lumbar neutral spine position and the subjects were asked to hold this position throughout the exercise.

Research protocol. The tests were done three times: the first testing occurred before exercises of training lumbar stability, the second – after four moths, and the third – after eight months of applying exercises for training lumbar stability. The subjects were engaged in an eight-month exercise program of training lumbar stability (two times per week, 45 min in each practice session). At the beginning of the research, after four moths and at the end of the research the women underwent the measurement of the cross-sectional area of the multifidus muscle. For the assessment of physical capacity we estimated the women's static strength endurance of back muscles and dynamic strength endurance of abdominal muscles.

Statistical analysis. Research data were processed by methods of descriptive statistics and more complicated statistics using program packages *Microsoft ® Excel 2007* and *SPSS 13*. The significance of mean differences was assessed using two-sided Student's *t* test for independent samples. The CSA of the multifidus muscle percentage expression of symmetry was calculated following the recommendations in research literature (Stokes et al., 2005).

RESEARCH RESULTS

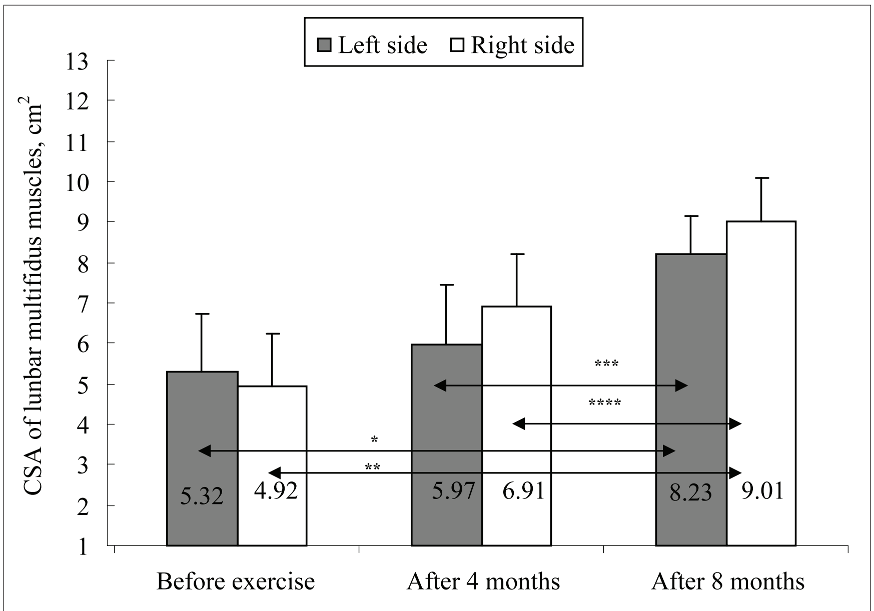
Research findings showed that after stability exercises the subjects had significantly larger *multifidus* CSA than before stability exercises.

Before stability exercises, CSA of the right side of the *lumbar multifidus* muscle was 4.92 ± 1.3, and the left side of the *lumbar multifidus* muscle was 5.32 ± 1.4. After 4 months, when the subjects had worked out in the group exercises (core stability exercises), CSA was significantly larger: the right side of the lumbar *multifidus muscle* was 6.91 ± 1.3; the left side – 5.97 ± 1.5 ($p < 0.05$). However after 8 months of stability exercises, the subjects had significantly larger right side *multifidus* CSA than before practice – 9.01 ± 1.1, the left side of the *lumbar multifidus* muscle was 8.23 ± 0.9 ($p = 0.05$) (Figure 2).

Before and after the lumbar core stabilization program, we evaluated the size of multifidus CSA between the left and the right sides. Figure 3 presents the mean percentage value of this index.

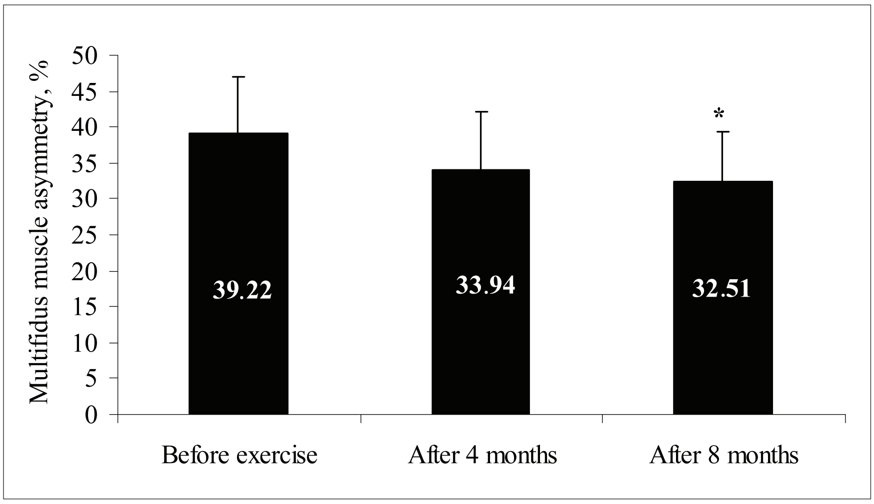
Before the lumbar core stabilization program the CSA of females was 39.22 ± 6.9%, after the lumbar core stabilization program a statistically significant ($p < 0.05$) decrease of CSA (32.51 ± 7.8%) was established.

Figure 2. **Cross-sectional area (left and right sides) of lumbar *multifidus* muscles**



Note. *, ** – p = 0.05 statistically significant differences in the values of the right and the left sides before and after eight months. ***,**** – p = 0.05 statistically significant differences in the values of the right and the left sides after four and after eight months.

Figure 3. **Lumbar *multifidus* muscle asymmetry**



Note. * – p = 0.05 significant decrease in CSA asymmetry comparing the indices before and after eight months.

Table. **Physical capacity indices before stability exercise, after four and eight months**

Physical capacity indicator	Before exercise	After 4 months	After 8 months	p-value
Dynamic strength endurance of abdominal muscles	25.4 ± 9.2 s (bad)	75.4 ± 4.4 s* (good)	97.6 ± 2.8 s* (perfect)	0.05
Static strength endurance of back muscles	15.3 ± 6.2 (moderate)	17.7 ± 3.1 (moderate)	25.6 ± 4.1* (higher than moderate)	0.05

Note. * – p = 0.05 significant increase compared to the values before stability exercise.

After the evaluation of physical capacity we revealed that after 4 months of exercising the static strength endurance of back muscles keeping the trunk in a horizontal position face down improved (75.4 ± 4.4 s (good)), and after 8 moths – 97.6 ± 2.8 s (very good), compared to the values before the research (25.4 ± 9.2) ($p < 0.05$) (Table).

The evaluation of the dynamic strength endurance of abdominal muscles showed that after the 8-month core stabilization exercise program the index values of women (25.6 ± 4.1, better than moderate) were better compared to the initial values before the research (15.3 ± 6.2, moderate) ($p < 0.05$). However, after the 4-months core stabilization exercise program we did not establish any statistically significant difference ($p > 0.05$) (Table).

DISCUSSION

Research results showed that after stability exercises the subjects had significantly larger *multifidus* CSA than before practice. After the core stabilization exercise program multifidus muscle asymmetry increased, physical capacities improved.

One of the most effective types of exercise is core muscle strengthening. This form of exercise concentrates on the abdominal and lower back muscles. The advantage of this form of exercise is that it can reduce lower back pain and reduce back injury by allowing proper alignment of the spinal column. Furthermore, functional reach can be increased with good core strengthening, reducing the risk of falling, especially in the elderly (Stokes et al., 2005). Classic trunk strengthening exercises involve activation of *abdominal* and *paraspinal* musculature at high levels of contraction. Such gross strengthening exercises differ from stability exercises in which there is preferential training to stabilize muscles, initially with low level isometric activation followed by progressive integration into everyday activities (Richardson et al., 1999; Norris, 2000). If performed incorrectly, classic trunk strengthening exercises may lead to inappropriate muscle coordination patterns and increased risk of further injury (Richardson et al., 1999, Cholewicki, McGil, 1996). In addition, exercises that are said to preferentially select *transversus abdominus* and *multifidus*, as described by C. Richardson et al. (1999) and P. B. O'Sullivan et al. (1997) are distinguished (MacDonald et al., 2006) from general trunk stabilization exercises, as described by S. McGill (2002). Decreased *lumbar multifidus muscle* activation is associated with the presence of factors predictive of clinical success with a stabilization *exercise* program (Hebert et al., 2010). J. A. Hides et al. (2008 b) found that the CSA of the *multifidus* muscles at the L5 vertebral level increased for the 7 cricketers with low back pain who received the stabilization training, compared to the 14 cricketers without low back pain who did not receive rehabilitation (p = 0.004). In addition, the amount of *muscle* asymmetry among those with low back pain significantly decreased (p = 0.029) and became comparable to cricketers without low back pain. These effects were not evident for the L2, L3, and L4 vertebral levels. *Multifidus muscle* atrophy can exist in highly active, elite athletes with low back pain. Specific retraining resulted in an improvement in *multifidus muscle* CSA and this was concomitant with a decrease in pain. However L. A. Danneels et al. (2001) found that general stabilization exercises and dynamic intensive *lumbar* resistance training had no significant *effect* on the CSA of the *lumbar multifidus muscle* in patients with low back pain. The static holding component between the concentric and eccentric phase was found to be critical in inducing *muscle* hypertrophy during the first 10 weeks. Treatment consisting of stabilization training combined with an intensive *lumbar* dynamic-static strengthening programme seems to be the most appropriate method of restoring the size of the *multifidus muscle.*

Physical activity programs adapted to the elderly women have been proposed with the purpose of minimizing the alterations provoked by aging (Greve et al., 2009). We could see that after the core stabilization exercise program physical capacities were better for elderly women. I. G. Fatouros et al. (2005) verified that high intensity exercises for elderly women might maintain the strength gain, aerobic power and mobility for longer periods after ceasing the low intensity exercises. F. X. Gamelin et al. (2007) investigated the effects of 12 weeks of training and 8 weeks of lack of training on the heart frequency variability and on the VO_2max and observed that the last one decreased significantly between the second and the eighth weeks. The authors concluded that 8 weeks of lack of training allowed a reverse of the cardiovascular adaptations induced by 12 weeks of training on elderly women.

CONCLUSION AND PERSPECTIVES

After the core stabilization exercise program *multifidus* CSA was significantly larger than before practice, multifidus muscle asymmetry increased. Physical activity programs adapted to the elderly women increased physical capacities. Further research is needed to evaluate the effectiveness of stabilization techniques and expectation for ensuring spinal stability when the healthy or unstable spine is loaded in different directions, postures and motions.

REFERENCES

Cholewicki, J., McGil, S. M. (1996). Mechanical stability of the *in vivo* lumbar spine: Implications of injury and chronic low back pain. *Clinical Biomechanics,* 11, 1–15.

Danneels, L. A., Vanderstraeten, G. G., Cambier, D. C. et al. (2001). Effects of three different training modalities on the cross sectional area of the lumbar multifidus muscle in patients with chronic low back pain. *British Journal of Sports Medicine,* 35, 186–191.

Fatouros, I. G., Kambas, A., Katrabasas, I. et al. (2005). Strength training and detraining effects on muscular strength, anaerobic power, and mobility of inactive older men are intensity dependent. *British Journal of Sports Medicine*, 39, 776–780.

Fraga, M. J., Cader, S. A., Ferreira, M. A. et al. (2011). Aerobic resistance, functional autonomy and quality of life (QoL) of elderly women impacted by a recreation and walking program. *Archives of Gerontology and Geriatrics,* 52 (1), 40–43.

Gamelin, F. X., Berthoin, S., Sayah, H. et al. (2007). Effect of training and detraining on heart rate variability in healthy young men. *International Journal of Sports Medicine*, 28, 564–570.

Greve, P., Wanderley, F. S., Rebelatto, J. R. (2009). The effects of periodic interruptions of physical activities on the physical capacities of adult active women. *Archives of Gerontology and Geriatrics,* 49, 268–271.

Hagberg, J. M. (1989). Cardiovascular response of 70–79-year-old men and women to exercise training. *Journal of Applied Physiology,* 66, 2589–2594.

Hauer, K., Becker, C., Lindemann, U., Beyer, N. (2006). Effectiveness of physical training on motor performance and fall prevention in cognitively impaired older persons: A systemic review. *American Journal of Physical Medicine and Rehabilitation,* 85, 847–857.

Hayden, J. A., van Tulder, M. W., Malmivaara, A., Koes, B. W. (2005). Exercise therapy for treatment of non-specific low back pain. *The Cochrane Database of Systematic Reviews [electronic resource]*, 20 (3), CD 000335.

Hebert, J. J., Koppenhaver, S. L., Magel, J. S., Fritz, J. M. (2010). The relationship of transversus abdominis and lumbar multifidus activation and prognostic factors for clinical success with a stabilization exercise program: A cross-sectional study. *Archives of Physical Medicine and Rehabilitation,* 91, 78–85.

Hides, J. A., Gilmorea, C., Stanton, W., Bohlscheid, E. (2008 a). Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. *Manual Therapy,* 13, 43–49.

Hides, J. A., Richardson, C. A., Jull, G. A. (1995). Magnetic resonance imaging and ultrasonography of the lumbar multifidus muscle-comparison of two different modalities. *Spine,* 20, 54–58.

Hides, J. A., Stanton, W. R., McMahon, S. et al. (2008 b). Effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with low back pain. *Journal of Orthopaedic and Sports Physical Therapy,* 38, 101–108.

Jankelowitz, S. K., McNulty, P. A., Burke, D. (2007). Changes in measures of motor axon excitability with age. *Clinical Neurophysiology,* 118, 1397–1404.

Kiesel, K. B., Uhl, T. L., Underwood, F. B. et al. (2007). Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Manual Therapy,* 12, 161–166.

MacDonald, D. A., Moseley, G. L., Hodges, P. W. (2006). The lumbar multifidus: Does the evidence support clinical beliefs? *Manual Therapy,* 11, 254–263.

McGill, S. (2002). *Low Back Disorders. Evidence-based Prevention and Rehabilitation.* Champaign: Human Kinetics.

Norris, C. M. (2000). *Back Stability*. Champaign: Human Kinetics.

Richardson, C., Jull, G., Hodges, P., Hides, J. (1999). *Therapeutic Exercises for Spinal Segmental Stabilization in Low Back Pain.* Edinburgh: Churchill Livingstone.

Stokes, M., Rankin, G., Newham, D. J. (2005). Ultrasound imaging of lumbar multifidus muscle: Normal reference ranges for measurements and practical guidance on the technique. *Manual Therapy,* 10 (2), 116–126.

O'Sullivan, P. B., Twomey, L. T., Allison, G. T. (1997). Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. *Spine,* 22, 2959–2967.

Vera-Garcia, F. J., Elvira, J. L. L., Brown, S. H. M. M., McGill, S. M. (2007). Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. *Journal of Electromyography and Kinesiology,* 17, 556–567.

Volbekienė, V. (2003). *Eurofitas. Fizinio pajėgumo testai ir metodika*. Vilnius: LSIC. P. 109–125.

Zhong, S., Chen, C. N., Thompson, L. V. (2007). Sarcopenia of ageing: Functional, structural and biochemical alterations. *Revista Brasileira de Fisioterapia,* 11, 91–97.

STUBURO STABILIZAVIMO PRATIMŲ POVEIKIS DAUGINIO RAUMENS SKERSPJŪVIO PLOTO IR FIZINIO PAJĖGUMO KAITAI

Irina Klizienė[1], Saulė Sipavičienė[2], Daiva Imbrasienė[2], Šarūnas Klizas[2], Hermanas Inokaitis[2]

Kauno technologijos universitetas[1], Kaunas, Lietuva
Lietuvos kūno kultūros akademija[2], Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tyrimo naujumas: ultragarinės diagnostikos metodu buvo matuojamas dauginio raumens skerspjūvio plotas, stebimi jo pokyčiai atliekant pratimus, kuriais siekiama stabilizuoti juosmeninę stuburo dalį.

Tikslas: nustatyti stuburo stabilizavimo pratimų poveikį vyresniojo amžiaus moterų dauginio raumens skerspjūvio ploto ir fizinio pajėgumo kaitai.

Metodai. Tiriamųjų kontingentą sudarė 22 moterys, jaučiančios nespecifinį juosmeninės stuburo dalies skausmą. Dauginio raumens skerspjūvio plotas matuotas naudojant ultragarsinę diagnostinę aparatūrą „TITAN™" (*SonoSite*, JAV), lygiagrečiai ultragarsu buvo nuskaitoma abiejose stuburo pusėse, ties L2–L5 slanksteliais. Nustatant fizinį pajėgumą vertinta pilvo preso raumenų dinaminė jėga ir nugaros raumenų statinės jėgos ištvermė. Tirta tris kartus: pirmas tyrimas atliktas prieš stuburo stabilizavimo pratimus, antras – po keturių, trečias – po aštuonių mėnesių stuburo stabilizavimo pratimų programos.

Rezultatai. Po aštuonių mėnesių stuburo stabilizavimo pratimų programos tiriamųjų dešinės (9,01 ± 1,1) ir kairės (8,23 ± 0,9) pusės dauginio raumens skerspjūvio plotas statistiškai reikšmingai ($p < 0,05$) padidėjo, nugaros raumenų statinės jėgos ištvermė buvo geresnė (97,6 ± 2,8 s (labai gerai)) negu prieš tyrimą (25,4 ± 9,2 s) ($p < 0,05$).

Aptarimas ir išvados. Atliekant stuburo stabilizavimo pratimus, dauginio raumens skerspjūvio plotas padidėjo, asimetrija – sumažėjo, pagerėjo tirtų moterų fizinio pajėgumo rodikliai.

Raktažodžiai: stuburo stabilizavimas, fizinio aktyvumo programa, amžius.

Gauta 2011 m. birželio 7 d.
Received on June 7, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Irina Klizienė**
Kaunas University of Technology
Donelaičio str. 73, LT-44248 Kaunas
Lithuania
Tel +370 37 453511
E-mail irina.ramanauskiene@ktu.lt

ACUTE EFFECTS OF DIFFERENT STRETCHING DURATIONS ON VERTICAL JUMP PERFORMANCE IN RHYTHMIC GYMNASTS

Nuriye Özengin[1], Necmiye Ün Yıldırım[1], Gül Baltacı[2] , Nerijus Masiulis[3]
Abant İzzet Baysal University[1], Bolu, Turkey
Hacettepe University[2], Ankara, Turkey
Lithuanian Academy of Physical Education[3], Kaunas, Lithuania

ABSTRACT

Research background. Stretching is believed to enhance performance, reduce injury, and be an effective means of developing flexibility and alleviating muscular soreness (Shellock, Prentice, 1985; Brandy et al., 1997). A review of the current literature shows that the results of many studies conflict with others; some report that static stretching diminishes vertical jum (VJ) performance (Cornwell et al., 2001; McNeal, Sands, 2003; Wallmann et al., 2005), whereas others report that static stretching has no effect at all on VJ (Church et al., 2001; Power et al., 2004; Unick et al., 2005).

Research aim, was to examine the effects of different durations of stretching on performance and to find the stretching durations that affect the performance negatively or positively.

Research methods. The subjects of the study were 27 rhythmic gymnasts with the mean age of 10.00 ± 1.2 years. The subjects as a whole group participated in two different stretching programs on nonconsecutive days to eliminate the effect of individual differences on the performance. On the first day, athletes were asked to warm up by 5 minute jogging after the pretest was administered. The posttest measured the vertical jump performance after athletes stayed inactive for 20 minutes. They rested for a day and on the third day, their performance was measured again. After the 5 minute warm-up period, 10 repetitions of 15 seconds static stretching exercises for hip flexor, hamstring and gastrocnemius muscle groups were followed by the posttest. Moreover, on the fifth day 30-second exercises were repeated five times on the same type of muscles. The participants in this investigation were tested in individual vertical jump performances following warm-up only, warm-up plus 15 seconds static stretching, and warm-up plus 30 seconds.

Research results. Results of a one-way repeated-measures ANOVA indicated a nonsignificant difference for vertical jump performance ($F = 2.052$; $p > 0.05$).

Discussion and conclusions. Stretching exercises are referred in rhythmic gymnastics more intensively than other sports. Relevant literature displays fewer stretching repetitions and durations. These durations and repetitions may not be realistic and practical for rhythmic gymnasts. Therefore, the durations and repetitions utilized in this study are considered more appropriate for rhythmic gymnastics trainings.

Rhythmic gymnasts may make use of duration and repetitions determined in this study that will not affect their performance.

Keywords: anaerobic power, gymnastics, exercise.

INTRODUCTION

Stretching is commonly used by athletes in different sports. Stretching can alter the range of motion about a joint and improve flexibility (Stone et al., 2006). However, stretching as part of a warm-up may reduce performance. Most available data indicates that acute performance reduction can occur and it may be related to decreased tissue stiffness or alterations in nervous system components of the stretch-shortening cycle, such as the myototic reflex (Stone et al., 2006). These alterations in turn can result in a decreased maximum strength and explosiveness and inferior performances (Stone et al., 2006). Several studies were carried out on vertical jump performance to see the effect of stretching. A. G. Nelson et al. (1996) investigated vertical jump performance after passive stretching in untrained men. They reported a decrease in vertical jump height after both countermovement and squat jumps after stretching the hip extensors and knee flexors (Nelson et al., 1996). J. B. Church et al. (2001) identified a decrease in vertical jump performance after an intervention of proprioceptive neuromuscular facilitation (PNF) of the hamstrings and quadriceps muscles on 40 female participants (Church et al., 2001). A. Cornwell et al. (1999) investigated the effects of passive stretching of triceps surae on static jump and countermovement jump performance. They concluded that there was a significant decrease in countermovement jump after stretching of the triceps surae complex (Cornwell et al., 1999).

Although available research findings displayed decrease in the performance due to acute stretching, stretching seems to be very important in high stretch-shortening cycles (SSCs) sports**.** It is generally accepted that increasing the flexibility of a muscle-tendon unit promotes better performances and decreases the number of injuries (Witvrouw et al., 2004). Muscle-tendon units can store mechanical work as elastic energy during eccentric contractions. The storage and subsequent release of elastic energy during SSCs have generally been considered as an 'energy-saving' mechanism (van Ingen Schenau et al., 1997). Therefore, it seems that different types of sports need different levels of musculo-tendinous stifness. Sports involving bouncing and jumping activities with a high intensity of SSCs (e.g. soccer and football) require a muscle-tendon unit that is stiff enough to store and release the high amount of elastic energy that benefits performance in such sports (Witvrouw et al., 2004).

S. Magnusson et al. (2000) showed that 3 sets of 45 seconds of stretching had no acute effect on the viscoelastic properties of the hamstring muscle (Magnusson et al., 2000). J. Unick et al. (2005) suggested that the quantity of stretching used in their study (3 sets of 15 seconds) may not have been enough to alter the viscoelastic properties of the muscles (Unick et al., 2005). A. di Cagno et al. (2010) concluded that more than 30 seconds for each stretch exercise duration has a detrimental effect on performances. K. Power et al. (2004) found plantar flexors, hamstrings, and quadriceps activation impairment because of SS held for 4.5 minutes (Power et al., 2004).

Gymnasts represent a group of athletes for whom stretching is a major component of training (Sands, 1988; Sands, McNeal, 2000). Gymnasts often perform a variety of active and passive stretches as part of their warm-up, as well as during their sport specific training activities (McNeal, Sands, 2003). The current literature lacks such research on female rhymtic gymnasts. Hence, this study aims at filling this gap by examining the acute effects of streching exercises on performances of females between the age of 8 and 12. The purpose of this study was to examine the acute effects of different stretching durations on vertical jump performance in female rhythmic gymnasts.

RESEARCH METHODS

Subjects. Thirty-five female rhythmic gymnasts initially volunteered to take part in this study. Five rhythmic gymnasts did not complete all study procedures, and 3 rhythmic gymnasts with pre-existing lower extremity injuries were not permitted to participate. No subject withdrew due to injury or any other adverse experiences. The final sample consisted of 27 rhythmic gymnasts. The mean ± SD for age, height, weight and body mass index of subjects who completed all study procedures was 10.00 ± 1.20 years, 1.37 ± 0.08 m, 31.66 ± 6.33 kg and 16.63 ± 1.43 kg/m^2 respectively. Families and trainers of the subjects were verbally informed of the procedures, and read and signed a consent form before the study. The study was approved by the Abant Izzet Baysal University Ethics Committee.

Procedures. Stretching program was practiced on nonconsecutive days. Two different stretching programs with two different stretching durations were applied to all athletes. Performance of athletes was evaluated both before and as soon as possible after the stretching. The subjects as a whole group participated in two different stretching programs on nonconsecutive days to eliminate the effect of individual differences on the performance. On the first day, athletes were asked to warm up by 5 minute jogging after the pretest was administered. The posttest measured the vertical jump performance after athletes stayed inactive for 20 minutes. They rested for a day and on the third day, their performance was measured again. After the 5 minute warm-up period, 10 repetitions of 15 seconds static stretching exercises on hip flexor, hamstring and gastrocnemius for each muscle groups were followed by the posttest. Moreover, on the fifth day 30-second exercises were repeated five times on the same type of muscles. Stretching

Table 1. **Stretching protocols applied to athletes in this study**

1st day	2nd day	3rd day	4th day	5th day
Measurement of performance (pre-test) ↓ Warm-up ↓ 20 min rest ↓ Measurement of performance (post-test)	Rest	Measurement of performance (pre-test) ↓ Warm-up ↓ 15 sec – 10 repetitions static stretching exercises to hip flexor, hamstring and gastrocnemius ↓ Measurement of performance (post-test)	Rest	Measurement of performance (pre-test) ↓ Warm-up ↓ 30 sec – 5 repetitions static stretching exercises to hip flexor, hamstring and gastrocnemius ↓ Measurement of performance (post-test)

protocols that were applied are summarized in Table 1.

Stretching Protocol. The two types of stretching durations and repetitions used in this study were 10 repetitions of 15 seconds and 5 repetitions of 30 seconds. All stretching were held to the onset tension, which was explained to the subjects as stretchings the muscle to the greatest voluntary length beyond which the subjects would feel pain might occur. The stretching protocol consisted of the following 3 stretches targeting muscles: hip flexors, hamstring, and gastrocnemius.

To stretch the hip flexors forward lunge was utilized. First, subjects stepped forward with the non-stretched leg and flexed this knee until it was directly over the foot, keeping it flat on the floor and the back leg straight. Afterwards, the back foot pointed toward the front foot not necessarily placed the back heel on the floor. Subjects then kept their body upright and rested their hands on the hips or in front of the leg. Finally, they stretched towards the floor throughout the protocol duration. One-legged standing stretch was used to stretch the hamstrings. In the standing position, subjects placed their stretched leg on a padded bench. The non-stretched leg pointed ahead with knee either fully extended or just slightly flexed. In this position, each subject leaned forward from the hips towards the elevated foot while ensuring to maintain a straight back. During the stretching, the knee of the stretched leg remained in a neutral position. Subjects leaned forward until a mild discomfort was felt in the hamstrings. Upon reaching this position, each subject was asked to hold this stretch for the duration of the protocol.

In order to stretch the gastrocnemius, the standing straight knee stretch was used. The subjects faced a wall and leaned against it with outstretched arms while bending the front leg at approximately 90˚ and keeping the other leg fully extended behind the body. The heel of the back leg remained in contact with the floor at all times while the subjects dorsiflexed the ankle of extended back leg.

Jump Performance Test. The vertical jump test was originally used by C. Bosco et al. (1983) to assess the lower-limb explosive performance capacity. The test was performed on a contact platform (*Newtest*, Oulu, Finland), which gives the time the subject is on air in milliseconds. Prior to the test, athletes were asked to wear shorts and cotton shirt, and to take off their trainers. The subjects started with the foot of the designated testing leg on the contact mat and their hands on their hips, they were then instructed to squatted (approximately 120° knee angle) as quickly as possible and then jumped as high as possible in the ensuring concentric phase (Maulder, Cronin, 2005). Subjects performed three trials in the protocol and the best one was used in the analysis. Power output was calculated by the following equation:

Power (kg-m/sn): weight (kg) x distance (m)/ time (s).

Statistical Analyses. To determine the effect that the stretching duration had on the vertical jump test, a one-way repeated-measures analysis of variance (ANOVA) was used. This method provides a measure of the actual mean differences between stretching conditions. Any significant differences found by the one-way repeated-measures ANOVA were followed by paired t-test analysis. Statistical significance in this investigation was set at $p < 0.05$.

RESEARCH RESULTS

The participants in this investigation were tested in individual vertical jump performances following warm-up only, warm-up plus 15 seconds static stretching, and warm-up plus 30 seconds. Results

Table 2. **The vertical jump mean (SD) results**

Vertical jump (kg-m/s)	Pre-test (n = 27) X ± SD	Post-test (n = 27) X ± SD
1st day	16.17 ± 3.80	16.43 ± 4.24
3rd day	16.43 ± 4.24	16.12 ± 3.97
5th day	16.77 ± 4.04	16.73 ± 3.97

of a one-way repeated-measures ANOVA indicated a nonsignificant difference for vertical jump performance ($F = 2.052$; $p > 0.05$) (see Table 2).

DISCUSSION

The purpose of this study was to determine the acute effects of static stretching on vertical jump performance and to investigate different durations of acute stretching on performance in rhythmic gymnasts. In this study, no significant decrease in vertical jump performance was found in the 15 and 30 second static stretching duration. These results differed from several previous studies that found a decrease in vertical jump as a result of stretching (Cornwell et al., 2001; Young, Elliot, 2001; Cornwell et al., 2002; McNeal, Sands, 2003; Faigenbaum et al., 2005; Wallmann et al., 2005; Glenn et al., 2006; Behm, Kibele, 2007; Bradley et al., 2007; Vetter et al., 2007; Robbins, Scheuermann, 2008).

A few reasons can be theorized as to why vertical jump performance stayed unaltered. The present study consisted of female athletes. K. Kubo et al. (2003) investigated sex differences in the viscoelastic properties of tendon structures and found that women had decreased tendon stiffness in their medial gastrocnemius muscle as compared with the males within their study. An increase in muscle compliance has been forwarded as a hypothesis to explain the loss of muscular performance after static stretching. It is possible that women are less affected by static stretching because of their already reduced stiffness of the musculotendinous units of the targeted muscles (Kubo et al., 2003).

Time spent between static stretching exercise and vertical jump test is vital. Because the recovery of motor neuron excitability is other explanation as to why vertical jump performance was unaltered as a result of static stretching. Many previous researchers have used Hoffman reflex (H-reflex) measures as an indicator of changes in motorneuron excitability (Guissard et al., 1988; Avela et al., 1999; Earles et al., 2002). In a study by J. Avela et al. (1999), effect of prolonged and repeated stretching on sensitivity was examined. The results of their study found a depression of the H-reflex after stretching but showed that the strength of this reflex was almost completely recovered 4 minutes after stretching (Avela et al., 1999). W. Guissard et al. (1988) also studied the H-reflex and found it to quickly recover immediately following static stretching. Therefore, the "resting period" between the stretching phase and jumping phase could have allowed a return in neuromotor excitability, causing any alteration that had occurred to return the prestretching or near prestretching status (Unick et al., 2005). In this study, vertical jump performance measurement was carried out longer than 4 minutes after static stretching to allow time for subjects to get prepared.

Several studies found that static stretching did not result in a performance decrease (Power, 2004; Guissard, Reiles, 2005; Cramer, 2007; Ufuk, David, 2007; Beedle, 2008; Cé et al., 2008; Samuel, 2008). Additionally, W. Young and S. Elliot (2001) found a nonsignificant decrease in the squat jump with 45 seconds of stretching per muscle group (3 sets of 15 seconds). J. B. Church et al. (2001) used women in their study comparing proprioceptive neuromuscular facilitation and static stretching and found that static stretching did not affect vertical jump. L. Burkett et al. (2001) studied the effectiveness of two specific and nonspecific warm-ups on vertical jump performance in women athletes and observed that a static stretching routine did not cause any significant changes to vertical jump when compared with the control condition. J. Unick et al. (2005) investigated the acute effects of static and ballistic stretching on vertical jump and concluded that neither stretching routine affected performance.

It is known that stretching exercises to enhance the flexibility are included both in the training programs and warm-up activities of many athletes (Gleim, McHugh, 1997). Sports involving "explosive" type skills (e. g. gymnastics), with many and maximal SSC movement require a muscle-tendon unit which is stiff enough to store and release the high amount of elastic energy.

Recently, it has been shown that stretching is able to increase the compliance of human tendons and, as a result increase the capacity of the tendon to absorb energy. When an individual's muscle-tendon unit is less flexible in these types of sports activities, there exists a predisposing factor for exercise-related injuries since the tendon is unable to absorb enough energy, which may lead to tendon and/or muscle damage (Witvrouw et al., 2004). Moreover, whether stretching exercises before the trainings negatively affect the performance or not are still confusing. This study examining the effect of 15 and 30 seconds static stretching on the performance of gymnasts show no change in the vertical jump test values after the 15 and 30-second stretching.

CONCLUSIONS AND PERSPECTIVES

Stretching exercises are referred in rhythmic gymnastics more intensively than other sports. Relevant literature displays fewer stretching repetitions and durations. These durations and repetitions may not be realistic and practical for rhythmic gymnasts. Therefore, the durations and repetitions utilized in this study are considered more appropriate for rhythmic gymnastics training. We concluded that rhythmic gymnasts may make use of duration and repetitions determined in this study that will not affect their performance.

REFERENCES

Avela, J., Kryolainen, H., Komi, P., Rama, D. (1999). Reduced reflex sensitivity persists several days after long-lasting stretch-shortening cycle Exercise. *Journal of Applied Physiology,* 86, 1292–1300.

Bandy, W. D., Irion, J. M., Briggler, M. (1997). The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Physical Therapy,* 77, 1090–1096.

Beedle, B., Rytter, S. J., Healy, R. C., Ward, T. R. (2008). Pretesting static and dynamic stretching does not affect maximal strength. *Journal of Strength and Conditioning Research,* 22 (6), 1838–1843.

Behm, D. G., Kibele, A. (2007). Effects of differing intensities of static stretching on jump performance. *European Journal of Applied Physiology,* 101, 587–594.

Bosco, C., Luhtanen, P., Komi, P. V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology,* 50, 273–282.

Bradley, P. S., Olsen, P. D., Portas, M. D. (2007). The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *Journal of Strength and Conditioning Research,* 21 (1), 223–226.

Burkett, L., Ziuraitis, J., Philipis, W. (2001). The effect of four different warm-ups on the maximum vertical jump test scores for female college athletes. *Women in Sport and Physical Acitivity Journal,* 10, 83–94.

di Cagno, A., Baldari, C., Battaglia, C. et al. (2010). Preexercise static stretching effect on leaping performance in elite rhythmic gymnasts. *Journal of Strength and Conditioning Research,* 24 (8), 1995–2000.

Cé, E., Margonato, V., Casasco, M., Veicsteinas, A. (2008). Effects of stretching on maximal anaerobic power: The roles of active and passive warm-ups. *Journal of Strength and Conditioning Research,* 22 (3), 794–800.

Church, J. B., Wiggins, M. S., Moode, M. F., Crist, R. (2001). Effect of warm-up and flexibility treatments on vertical jump performance. *Journal of Strength and Conditioning Research,* 15, 332–336.

Cornwell, A., Nelson, A. G., Heise, G. D., Sidaway, B. (2001). Acute effects of passive muscle stretching on vertical jump performance. *Journal of Human Movement Studies,* 40, 307–324.

Cornwell, A., Nelson, A. G., Sidaway, B. (1999). Acute effects of passive stretcing on the neuromechanical behavior of the triceps surae muscle complex. *Medicine and Science in Sports and Exercise,* 31, S 221.

Cornwell, A., Nelson, A. G., Sidaway, B. (2002). Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. *European Journal of Applied Physiology,* 86, 428–434.

Cramer, J. T., Housh, T. J., Johnson, G. O. et al. (2007). An acute bout of static stretching does not affect maximal eccentric isokinetic peak torque, the joint angle at peak torque, mean power, electromyography, or mechanomyography. *Journal of Orthopaedic Sports Physical Therapy,* 37, 130–139.

Earles, D., Dierking, C., Robertson, C., Koceja, D. (2002). Pre- and post- synaptic control of motoneuron excitability in athletes. *Medicine and Sscience in Sports and Exercise,* 34, 1766–1772.

Faigenbaum, A. D., Bellucci, M., Bernieri, A. et al. (2005). Acute effects of different warm-up protocols on fitness performance in children. *Journal of Strength and Conditioning Research,* 19 (2), 376–381.

Gleim, G. W., McHugh, M. P. (1997). Flexibility and its effects on sports injury and performance. *Sports Medicine,* 24, 289–299.

Glenn, W., Lucinda, W., John, G., Carl, F. (2006). Effects of static stretching, dynamic stretching, and warm-up on active hip range of motion and vertical jump. *Medicine and Science in Sports and Exercise,* 38 (5), S 280–281.

Guissard, N., Duchateau, J., Hainaut, K. (1988). Muscle stretching and motoneuron excitability. *European Journal of Applied Physiology and Occupational Physiology,* 58, 47–52.

Guissard, N., Reiles, F. (2005). Effects of stretching and contract relax methods on the force production and jump performance. *Computer Methods in Biomechanics and Biomedical Engineering,* Supplement 1, 127–128.

van Ingen Schenau, G. J., Bobbert, M. F., de Haan, A. (1997). Does elastic energy enhance work and efficiency in the stretch-shortening cycle? *Journal of Applied Biomechanics,* 13, 389–415.

Kubo, K., Kanehisa, H., Fukunaga, T. (2003). Gender differences in the viscoelastic properties of tendon structures. *European Journal of Applied Physiology*, 88, 520–526.

Magnusson, S., Aagaard, P., Nielson J. (2000). Passive energy return after repeated stretches of the hamstring muscle-tendon unit. *Medicine and Science in Sports and Exercise,* 33, 1160–1164.

Maulder, P., Cronin, J. (2005). Horizontal and vertical jump assessment: reliability, symmetry, discriminative and predictive ability. *Physical Therapy in Sport*, 6, 74–82.

McNeal, J. R., Sands W. A. (2003). Acute static stretching reduces lower extremity power in trained children. *Pediatric Exercise Science*, 15, 139–145.

Nelson, A. G., Cornwell, A., Heise, G. D. (1996). Acute stretching exercises and vertical jump stored elastic energy. *Medicine and Science in Sports and Exercise,* 28, S 156.

Power, K., Behm, D., Cahill, F. et al. (2004). An acute bout of static stretching: Effects on force and jumping performance. *Medicine and Science in Sports and Exercise,* 36 (8), 1389–1396.

Robbins, J. W., Scheuermann, B. W. (2008). Varying amounts of acute static stretching and its effect on vertical jump performance. *Journal of Strength and Conditioning Research,* 22 (3), 781–786.

Samuel, M. N., Holcomb, W. R., Guadagnoli, M. A. et al. (2008). Acute effects of static and ballistic stretching on measures of stregth and power. *Journal of Strength and Conditioning Research,* 22 (5), 1422–1428.

Sands, W. A. (1988). Gymnastics Federation physical abilities testing for women. *Technique*, 8 (3–4), 27–32.

Sands, W. A., McNeal, J. R. (2000). Enhancing flexibility in gymnastics. *Technique*, 20, 6–9.

Shellock, F. G., Prentice, W. E. (1985). Warming up and stretching for improved physical performance and prevention of sports related injuries. *Sports Medicine,* 2, 267–278.

Stone, M., Ramsey, M. W., Kinser, A. M. et al. (2006). Stretching: Acute and chronic? The potential consequences. *Strength and Conditioning Journal,* 28 (6), 66–74.

Ufuk, A., David. K. (2007). The effects of acute static stretching on reaction time and force. *The Journal of Sports Medicine and Physical Fitness,* 47 (2), 147–150.

Unick, J., Keiffer, S. H., Cheesman, W., Feeney, A. (2005). The acute effects of static and ballistic stretching on vertical jump performance in trained women. *Journal of Strength and Conditioning Research,* 19 (1), 206–212.

Vetter, R. E. (2007). Effects of six warm-up protocols on sprint and jump performance. *Journal of Strength and Conditioning Research,* 21 (3), 819–823.

Wallmann, H. W., Mercer, J. A., McWhorter, J. W. (2005). Surface electromyographic assessment of the effect of static stretching of the gastrocnemius on vertical jump performance. *Journal of Strength and Conditioning Research,* 19 (3), 684–688.

Witvrouw, E., Mahieu, N., Danneels, L., McNair, P. (2004). Stretching and injury prevention an obscure relationship. *Sports medicine*, 34(7), 443-449.

Young, W., Elliot, S. (2001). Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Research Quarterly for Exercise and Sport,* 72, 273–282.

GREITOJI ADAPTACIJA PRIE MENINĖS GIMNASTIKOS VERTIKALIŲ ŠUOLIŲ ATLIEKANT SKIRTINGOS TRUKMĖS TEMPIMO PRATIMUS

Nuriye Özengin[1], Necmiye Ün Yıldırım[1], Gül Baltacı[2], Nerijus Masiulis[3]
Abant Izzet Baysal universitetas[1], Bolu, Turkija
Hacettepe universitetas[2], Ankara, Turkija
Lietuvos kūno kultūros akademija[3], Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Manoma, kad tempimo pratimai pagerina raumenų darbą, mažina traumų tikimybę ir yra veiksminga lankstumo lavinimo priemonė, padedanti mažinti raumenų skausmą (Shellock, Prentice, 1985; Brandy et al., 1997). Daugelio tyrimų rezultatai prieštarauja vieni kitiems – kai kuriuose teigiama, kad statinis tempimas sumažina raumenų veiklą vertikalių šuolių metu (Cornwell et al., 2001; McNeal, Sands, 2003; Wallmann et al., 2005), kiti teigia, kad statinis tempimas neturi jokio poveikio vertikaliems šuoliams (Church et al., 2001; Power et al., 2004; Unick et al., 2005).

Tikslas: ištirti, kaip įvairios trukmės tempimo pratimai veikia raumenų darbą ir nustatyti optimalią tempimo pratimų trukmę.

Metodai. Buvo tiriami 27 meninės gimnastikos sportininkai, kurių amžiaus vidurkis – 10,00 ± 1,2 metų. Ne tomis pačiomis dienomis visai grupei buvo taikomos dvi skirtingos raumenų tempimo pratimų programos. Pirmą dieną sportininkų buvo prašoma atlikti 5 minučių trukmės pramankštą bėgant. Po 20 minučių pertraukos išmatuotas vertikalaus šuolio aukštis, tada vieną dieną ilsimasi, o trečią – vėl vertinami šuoliai. Po pramankštos buvo taikomi statiniai dubens, šlaunies ir blauzdos raumenų tempimo pratimai atliekant 10 kartojimų po 15 sekundžių. Be to, penktą dieną toms pačioms raumenų grupėms buvo taikyti 30 sekundžių trukmės tempimo pratimai, kartojami po penkis kartus. Testuotas tik individualus tiriamųjų vertikalių šuolių atlikimas po pramankštos pratimų, po pramankštos ir po 15 sekundžių statinio tempimo, po pramankštos ir 30 sekundžių tempimo.

Rezultatai. Pakartotinių matavimų dispersinės analizės rezultatai parodė neesminius vertikalių šuolių atlikimo skirtumus ($F = 2{,}052$; $p > 0{,}05$).

Aptarimas ir išvados. Šis tyrimas neatskleidė pokyčių vertinant vertikalų šuolį. Meninės gimnastikos pratybose tempimo pratimai yra daugiau taikomi nei kitų sporto šakų. Literatūros šaltiniuose pateikiamos skirtingos tempimo pratimų kartojimo ir trukmės rekomendacijos. Šiuo tyrimu nurodoma pratimų atlikimo trukmė ir kartojimų skaičius labiau tinka per meninės gimnastikos pratybas, bet sportininkams didesnio poveikio neturi.

Raktažodžiai: anaerobinis galingumas, gimnastika, pratimas.

Gauta 2011 m. liepos 30 d.
Received on July 30, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Nuriye Özengin**
Abant İzzet Baysal University, Physical Therapy and Rehabilitation School
Bolu, Turkey
Tel +90 0374 253 46 61
E-mail ozenginnuriye@yahoo.com

DYNAMICS OF CENTRAL AND PERIPHERAL CARDIOVASCULAR INDICES WHILE PERFORMING REPETITIVE DOSED EXERCISE TEST

Kristina Poderienė, Eugenijus Trinkūnas, Jonas Poderys
Lithuanian Academy of Physical Education, Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Various physical loads require a different level of activation of various physiological systems and physiological mechanisms, which can highlight the synergetic interaction between central and peripheral mechanisms.

Research aim. The aim of this study of this study was to identify and compare the central and peripheral reactions of cardiovascular system while performing repetitive dosed exercise test.

Research methods. The participants in the study (15 persons in each of the four groups: non-athletes males; non-athletes females; well-trained endurance runners and well-trained sprinters) performed three Roufier exercise tests, i. e. 30 squats per 45 s with two minutes of rest between exercising. 12-leads ECG was registered and the heart rate (HR), the duration of interval JT were measured and analysed. Changes of oxygen saturation (StO_2) in m. vastus leteralis were measured by near-infrared spectroscopy.

Research results. One time performance of the physical load may not reveal any central and peripheral synergic peculiarities as adaptation to physical loads in cumulative. For non-athletes the performance of repetitive Roufier tests every two minutes produced the fatigue summation effects which were typical of central and peripheral indices; for well-trained athletes we observed the stability of central reaction and fatigue effects in peripheral responses.

Discussion and conclusions. A lot of cardiovascular indices may indicate the summation effects of fatigue while repeatedly performing a Roufier Test with two minutes of rest between exercising. The peripheral changes start first and they impact the central cardiovascular changes.

Keywords: electrocardiogram, dosed exercise test, oxygen saturation.

INTRODUCTION

While performing different movement tasks the activity of various functional systems are energized in different degrees and ways. The activity of controlling mechanisms appears in hierarchic interaction, thus providing information about the functional state of the system or the whole body (Grassi et al., 1996; Hughson, 2007; Jones, Pople, 2007). Cardiovascular system plays one of the most important roles in the constitution of the supplying systems, and the recognition of the processes taking place in the cardiovascular system is important while performing the testing procedures aimed at estimating the adaptation of the body functions to workloads or peculiarities of the recovery process (Perkiomaki, 2003; Vainoras, 2004). There are many studies designed for the assessment of central and peripheral mechanisms of regulation of muscular blood flow and oxygen supply to muscles and for better understanding of the interaction of the central and peripheral mechanisms; however, there is a great demand for the studies on the sequence and interaction of various mechanisms when physical exercises are performed under various conditions and at different intensities of exercising (Tschakovsky, Joyner, 2008).

The hypothesis of the present study was formulated taking into account the fact that various physical loads requiring a different level of activation of various physiological systems and physiological mechanisms may highlight the synergetic interaction between central and peripheral mechanisms. The aim of this study was to identify and compare the central and peripheral reactions of cardiovascular system while performing repetitive dosed exercise test.

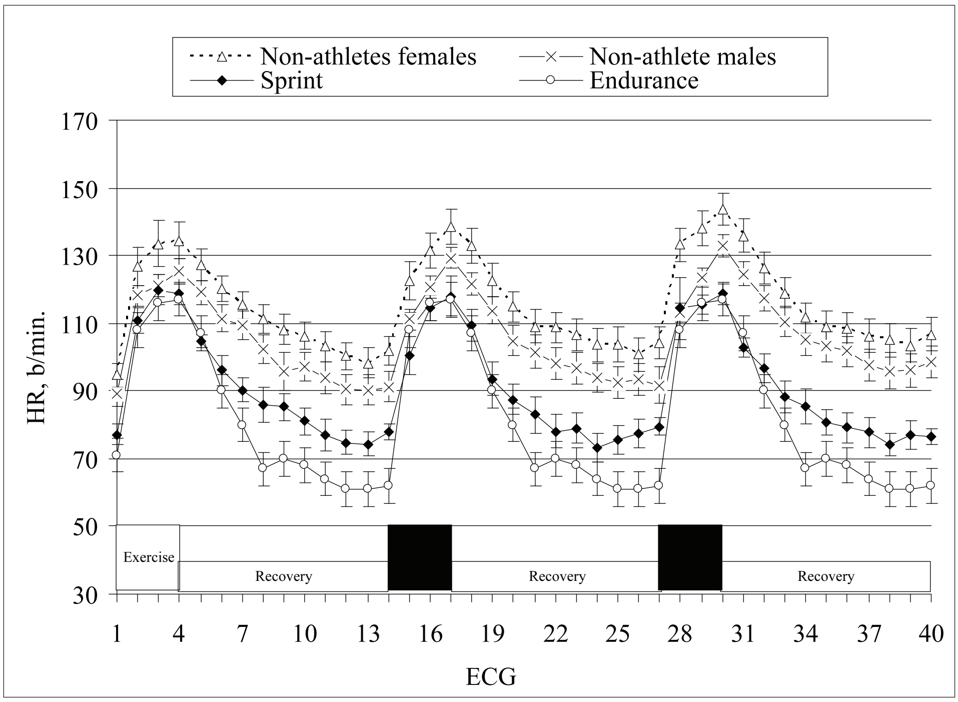
RESEARCH METHODS

Four groups of research participants in the study 15 persons in each group (*non-athletes males; non-athletes females; well-trained endurance runners and well-trained sprinters*) were engaged in to experiment. All participants performed three Roufier exercise tests, i. e. 30 squats per 45 s with two minutes of rest between each exercise. During the exercising and recovery the 12-leads ECG was registered using the computerised system "Kaunas-load". The heart rate (HR), the duration of interval JT of ECG, the ratio JT/RR were measured and analysed. Indirect ABP measurements were taken from the arm with a sphygmomanometer and standard-size arm cuff before the exercise test and after exercising during the first two minutes of recovery. Changes of oxygen saturation (StO_2) in a thigh muscle (*m. vastus leteralis*) were measured by near-infrared spectroscopy (*Hutchinson Technology Hutchinson*, Minnesota, USA device, Model 325). The increase of StO_2 after each repetitive workload in various cohorts was normalized, i. e. the baseline of StO_2 registered before exercise tests was set equal to 100 percent. The significance of the difference between values obtained at each testing was evaluated by computing t criterion; the paired and unpaired t-tests were used. The difference was considered statistically reliable, when p was < 0.05 (95 CI).

RESEARCH RESULTS

The results obtained during this study showed that the performance of repetitive exercising, i. e. while performing aerobic dosed workload produced different reactions which were dependant on the adaptation to exercising. Figure 1 presents the dynamics of HR in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them. Presented HR curves showed that in the non-athlete female cohort the specific feature was the highest values

Figure 1. **Dynamics of HR in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them**



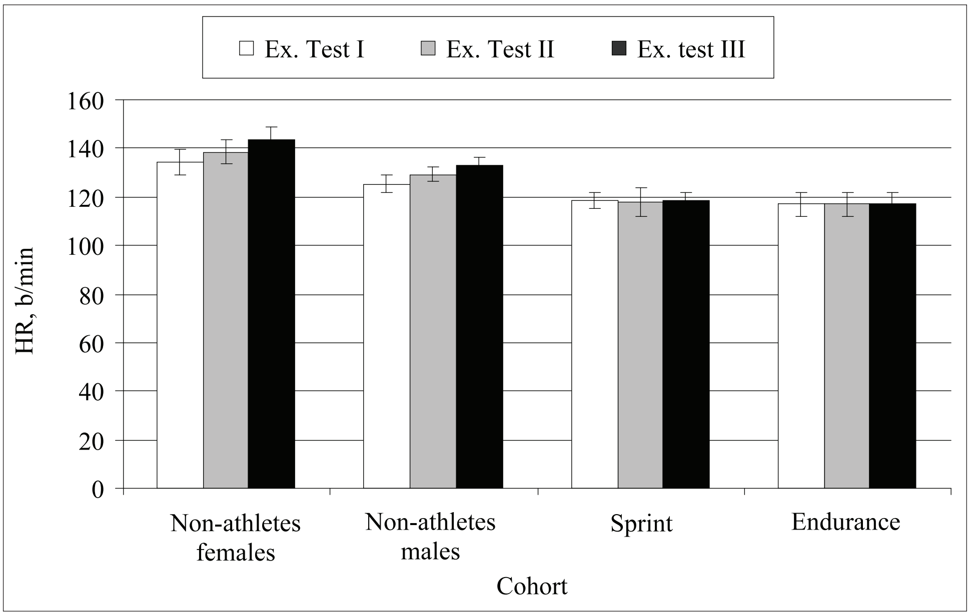


Figure 2. **Maximal values of HR registered at the end of exercise test in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them**

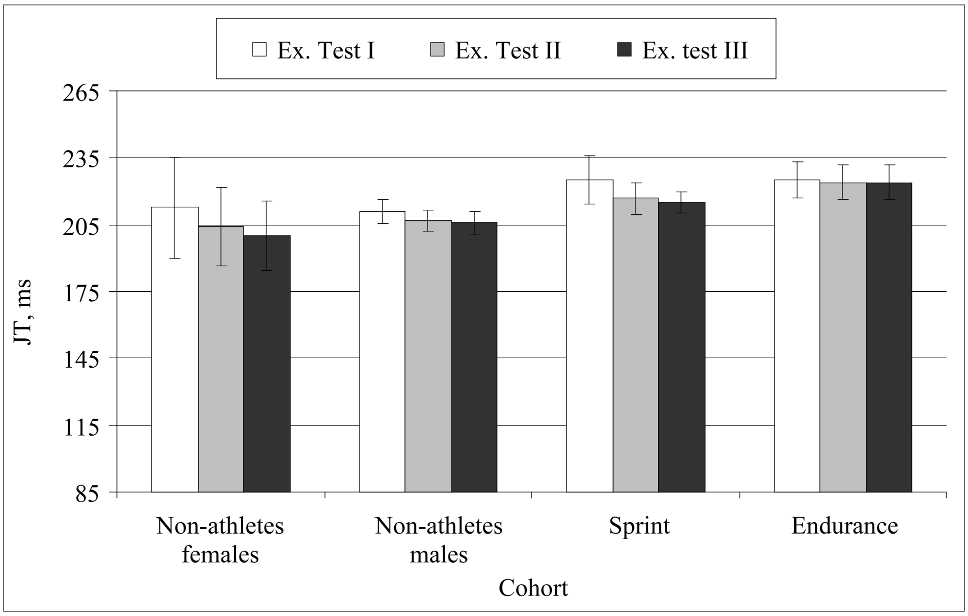


Figure 3. **Maximal values of JT interval registered at the end of exercise test in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them**

of HR at the rest (94.6 ± 3.35 b/min – in non-athlete female cohort; 89.4 ± 4.06 b/min – in non-athlete male cohort; 77.2 ± 2.93 b/min – in well-trained sprinters cohort and 71.2 ± 3.01 – in well-trained endurance runners cohort). The same peculiarities, i. e. the highest HR values in the non-athlete female cohort remained during the workloads. At the end of the first testing workload HR increased up to 134.3 ± 5.04 b/min in non-athlete female cohort; up to 125.4 ± 3.3 b/min – in non-athlete male cohort; up to 118.6 ± 3.9 b/min – in well-trained sprinters cohort and up to 117.2 ± 3.00 b/min – in well-trained endurance runners cohort. The same dynamics of HR was observed performing the second and the third testing workloads.

Figure 2 presents the maximal values of HR registered at the end of the exercise test in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them. Presented data indicate that there was no increase in maximal values of HR in two well trained athlete cohorts while performing repetitive exercises, i. e. there was no summing effect of fatigue taking into account the central reactions of the cardiovascular system. The results of other two cohorts (non-athlete males and non-athlete females) showed that HR increased with every second period of exercising, i. e. the summation of fatigue was evident. The same tendency was observed in the dynamics of JT interval (Figure 3). The decrease of JT interval at the end of workloads had the tendency to be bigger in both non-athlete groups and there were no significant changes between the shortest JT interval values in both athlete groups while performing Roufier test-workloads in a repetitive way.

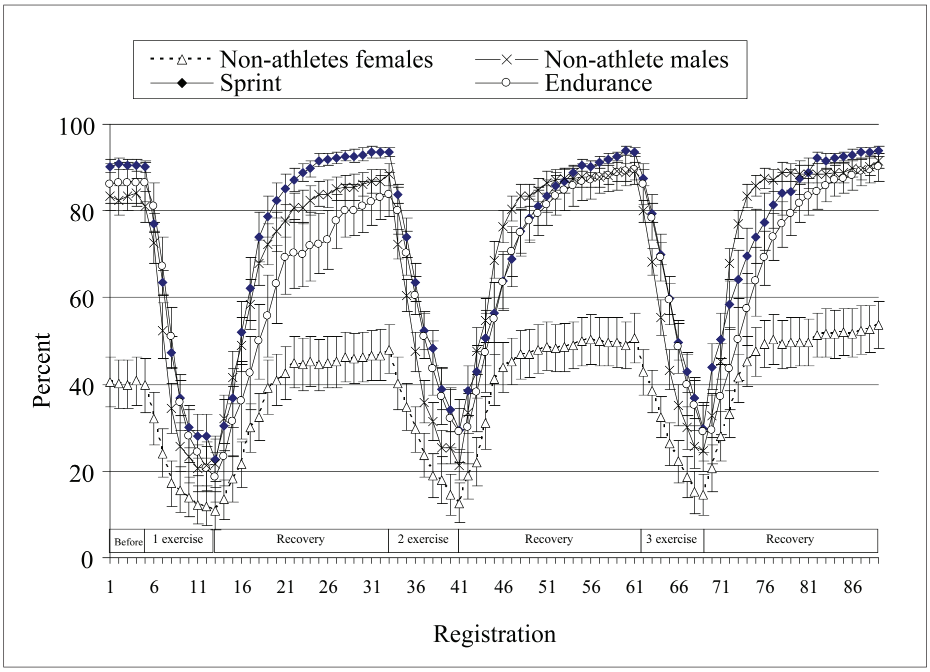


Figure 4. **Dynamics of StO_2 in four experimental cohorts while performing 3 dosed exercise tests with 2 minutes of recovery between them**

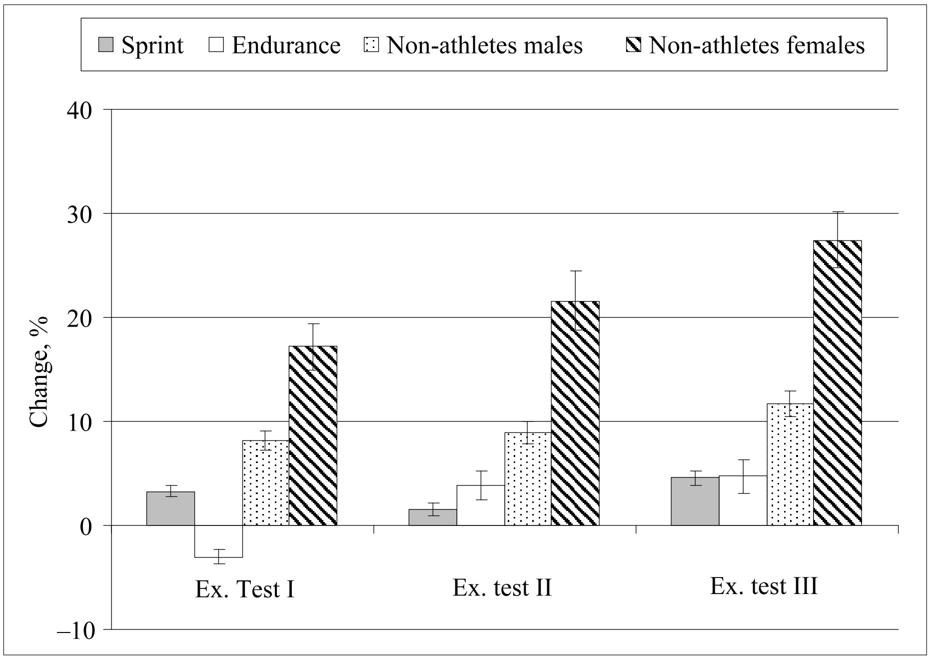


Figure 5. **Increase in StO_2 after 2minutes of recovery after exercising in four experimental cohorts**

Note. Initial value of StO_2 registered before an experiment is accepted as 100%.

Figure 4 shows the average dynamics of StO_2 during exercising and the recovery in four experimental cohorts. The data obtained during the study showed that non-athlete female cohort was characterized by lower baseline values of StO_2. Figure 5 shows the increase in StO_2 after 2 minutes of recovery after exercising in four experimental cohorts (the initial value of StO_2 registered before an experiment were accepted as 100%). The presented data showed that the effect of summation was observed in all four cohorts. The slowest increase was observed in the endurance cohort; a greater increase was found in the sprint cohort; still greater increase – in non-athlete male cohort and the greatest increase – in non-athlete female cohort.

DISCUSSION

Consideration of the interrelations of the factors affecting cardiovascular changes may lead to a better understanding of the regulation of muscle blood flow and the mechanisms, which may explain the sequence of changes of various cardiovascular indices at onset of exercising. Research literature contains some hypothesis concerning the possible leading triggers of cardiovascular changes at the onset of exercising but most of these possible explanations related to the intracellular signalling from blood vessels (Wernbom et al., 2008).

At the onset of exercise the cardiovascular system adapts with a series of integrated responses to meet the metabolic demands of exercising muscles (Hughson, Tschakovsky, 1999). Regulatory mechanisms of the systemic blood circulation are oriented to sustain a gradient of pressure necessary to insure the needed blood circulation intensity in organs and active muscles. This happens in the combination of the heart work indexes and changes in the total peripheral resistance (Ahlborg et al., 1996; Ursino, Magosso, 2003). Systematic research is needed in order to define the central and local mechanisms underlying cardiovascular responsiveness during exercising. Such information is important for designing future interventions aimed at improving muscle blood supply and functional capacity (Koch et al., 2005). Moreover important question is about the trigger of these changes, i. e. if peripheral or central changes start first.

The results obtained during the analysis of ECG indices showed only the difference between cohorts in the adaptation to exercising, i. e. there was no summation in fatigue in well trained athlete's cohorts, and the fatigue summation effect was evident in both non-athlete cohorts. On the basis of these results and the indices of central reactions of the cardiovascular system we could not came up to the conclusion what was the most important trigger. The results about the peripheral changes are needed, and it is important to find out if the peripheral or the central changes start first.

Post exercise hyperemia reflects the biological cost of performed workload, i. e. the changes in muscular tissue (Osada et al., 2003; Vinet et al., 2011). The results obtained during the study showed the increase in StO_2 at the second minute after testing workloads, i. e. the peripheral changes were observed in all four cohorts. This suggests and supports the notion that peripheral changes start first and they impact the central cardiovascular changes.

The non-athlete female cohort was characterized by lower baseline values of StO_2 which may be explained as an artefact of measurement technique, i. e. reduced by sub-subcutaneous fat layer, which was is a typical difference for this female cohort.

One time performance of the physical load may not reveal central and peripheral synergic peculiarities as adaptation to physical loads is cumulative. For non-athletes the performance of repetitive Roufier tests every two minutes produced the fatigue summation effects, which were typical of central and peripheral indices; for well-trained athletes we observed stability of central reaction and fatigue summation effects in peripheral responses.

CONCLUSIONS AND PERSPECTIVES

A lot of cardiovascular indices may indicate the summation effects of fatigue while repeatedly performing a Roufier Test with two minutes of rest between exercising. The peripheral changes start first and they impact the central cardiovascular changes.

REFERENCES

Ahlborg, G., Ottosson-Seeberger, A., Hemsen, A., Lundberg, J. M. (1996). Central and regional hemodynamic effects during infusion of Big endothelin-1 in healthy humans. *Cardiovascular Research* 80 (6), 1921–1927.

Grassi, B., Polle, D. C., Richardson, R. Set al. (1996). Muscle O_2 uptake kinetics in humans: Implications for metabolic control. *Journal of Applied Physiology*, 80, 988–998.

Hughson, R. L. (2007). Regulation of VO_2 on Kinetics by O_2 Delivery. In Jones A. M., Pool D. C. (Eds.), *Oxygen Uptake Kinetics in Sport, Exercise and Medicine*. London and New York: Routlege. P. 185–211.

Hughson, R. L., Tschakovsky, M .E. (1999) Cardiovascular dynamics at the onset of exercise. *Medicine and Science in Sport and Exercise,* 31 (7), 1005–1010

Jones, A. M., Pople, D. C. (Eds.). (2007). *Oxygen Uptake Kinetics in Sport, Exercise and Medicine*. London and New York: Routlege.

Koch, D. W., Newcomer, S. C., Proctor, D. N. (2005). Blood flow to exercising limbs varies with age, gender, and training status. *Canadian Journal of Applied Physiology,* 30 (5), 554–575.

Osada, T., Katsumura, T., Murase, N. et al. (2003) Post-exercise hyperemia after ischemic and non-ischemic isometric handgrip exercise. *Journal of Physiological Anthropometry and Applied Human Science,* 22 (6), 299–309.

Perkiomaki, S. J. (2003). Nonlinear dynamics of heart rate and repolarization. *International Journal of Bioelectromagnetism,* 5 (1), 300.

Tschakovsky, M. E., Joyner, M., J. (2008). Nitric oxide and muscle blood flow in exercise. *Applied Physiology, Nutrition and Metabolism,* 33 (1), 151–161.

Ursino, M., Magosso, E. (2003). Role of short-term cardiovascular regulation in heart period variability: A modeling study. *American Journal of Physiology – Heart and Circulatory Physiology,* 284 (4), H 1479–493.

Vainoras, A. (2004). *Kompleksinių sistemų bendrosios ypatybės, sinergetika. Kineziologijos pagrindai*. Kaunas. P. 189–194.

Vinet, A., Karpoff, L., Walther, G. et al. (2011). Vascular reactivity at rest and during exercise in middle-aged obese men: Effects of short-term, low-intensity, exercise training. *International Journal of Obesity, (London),* 35 (6), 820–828.

Wernbom, M., Augustsson, J., Raastad, T. (2008). Ischemic strength training: A low-load alternative to heavy resistance exercise? *Scandinavian Journal of Medicine & Science in Sports*, 18, 401–416.

PERIFERINĖS BEI CENTRINĖS ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS FUNKCINIŲ RODIKLIŲ KAITA ATLIEKANT KARTOTINIUS DOZUOTO FIZINIO KRŪVIO MĖGINIUS

Kristina Poderienė, Eugenijus Trinkūnas, Jonas Poderys
Lietuvos kūno kultūros akademija, Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Atliekant įvairius fizinius krūvius, nevienodai aktyvuojamos organizmo fiziologinės sistemos ir mechanizmai, todėl tokios studijos gali atskleisti sinerginę centrinių ir periferinių mechanizmų sąveiką.

Tikslas: nustatyti ir palyginti centrinės bei periferinės širdies ir kraujagyslių sistemos funkcinių rodiklių kaitos ypatybes atliekant kartotinius dozuoto fizinio krūvio mėginius.

Metodika. Buvo tiriamos keturios grupės (po 15 tiriamųjų kiekvienoje) nesportuojančių merginų, nesportuojančių vaikinų ir dvi didelio meistriškumo sportininkų (sprinto ir ištvermės). Tiriamieji atliko tris dozuoto fizinio krūvio mėginius (Rufjė testą, t. y. 30 pritūpimų per 45 s, darant dviejų minučių poilsio pertrauką tarp krūvių). Dvylika standartinių derivacijų buvo nenutrūkstamai registruojama elektrokardiograma (EKG) įvertinant ŠSD ir EKG JT intervalo pokyčius. Deguonies įsotinimo šlaunies raumenyje kaita registruota neinvazinės artimosios spektroskopijos metodu.

Rezultatai. Atliekant vienkartinį dozuotą fizinį krūvį, daugelis sinerginių centrinių ir periferinių ŠKS ypatybių gali neišryškėti, nes individualūs ir adaptacijos prie fizinių krūvių rodikliai sumuojasi. Kas dvi minutes atliekant kartotinius Rufjė fizinio krūvio mėginius, psireiškia nesportuojančių asmenų nuovargio sumavimosi efektai; vidutinio meistriškumo sportininkų – centrinių ŠKS funkcinių rodiklių reakcija į pirmą pratimo kartojimą; didelio meistriškumo sportininkų – funkcinių rodiklių atkartotinumas (reakcijų stabilumas).

Aptarimas ir išvados. Kas dvi minutes atliekant kartotinius Rufjė fizinio krūvio mėginius, daugumos ŠKS funkcinių rodiklių kaita rodo suminį fizinio krūvio efektą. Periferinių funkcijų pokyčiai pasireiškia pirmiau ir veikia kitus centrinės ŠKS funkcinius rodiklius.

Raktažodžiai: elektrokardiograma, dozuoto krūvio mėginiai, deguonies pasisavinimas.

Gauta 2011 m. liepos 25 d.
Received on July 25, 2011

Priimta 2011 m. rugsėjo 9 d.
Acceprted on September 9, 2011

Corresponding author **Kristina Poderienė**
Aušros str. 42–31, LT-44221 Kaunas
Lithuanian Academy of Physical Education
Lithuania
Tel +370 37 302650
E-mail k.poderyte@lkka.lt

INTERACTION OF TRAINING AND PERFORMANCE OF 13–14-YEAR-OLD ATHLETES IN RHYTHMIC GYMNASTICS

Renata Rutkauskaitė, Antanas Skarbalius
Lithuanian Academy of Physical Education, Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. The efficacy of athlete's sport performance depends on the targeted training in certain periods, organization, management, individual adaptation of an athlete to the loads of training and competitions.

Research aim was to determine the impact of specific training on sport performance of 13–14-year-old athletes in rhythmic gymnastics.

Research methods. The experiment resulted in modeling three different training programs and establishing the structure of the content of the training programs, as well as athletes' sport performance. The training load protocols registered the time for choreography, element mastering, competitive routines and athletic training in each training session. The efficacy of the training programs was established registering the realization of competitive activities under competitive conditions, according to the number of points received by the gymnast of each training program, according to the place won.

Research results. Training athletes in three training programs differed – their training loads were significantly different – from 10.28 to 12.91 hours a week, as well as the indices of the training days – from 5.43 to 4.17 days a week, the training content differed significantly. In the most effective training program choreographic training (35.8%) dominated. Statistically significant differences ($p < 0.05$) were found in the indices of explosive strength and muscular power, specific endurance, coordination movement abilities and the integral index of athletic fitness. At the beginning of the season and at the end of it the realization of the body movement technique performing routines with different tools was different ($p < 0.001$).

Discussion and conclusions. In the period of individual training of 13–14-year-old athletes in rhythmic gymnastics time for mastering competitive routines and integral training became more significant for the efficacy of athletes' sport performance. The indices of movement with different tools technique became more significant and the indices of difficulty of body movement technique remained stable. The most important factors influencing sports performance were explosive strength, strength endurance, coordination, and the total integral index of athletic fitness.

Keywords: rhythmic gymnastics, training, performance.

INTRODUCTION

The efficacy of athlete's sport performance depends on the targeted training in certain periods, organization, management, individual adaptation of an athlete to the loads of training and competitions (Mester, Perl, 2000; Torrents et al., 2001; Edelmann-Nusser et al., 2002). If the requirements of athlete training mentioned above are followed, there are premises for their successful participation in the most important international competitions.

While registering and analyzing competitive activities it is possible to establish the level of their interaction with different components of athlete training (Mester, Perl, 2000; Perl, 2004). Besides, registering and analyzing competitive activities enable us to foresee the tendencies of a sport, forecast

Table 1. **Anthropometric characteristics of subjects ($\bar{x}$ ± SD)**

Training groups	Age, years	Height, cm	Body mass, kg	BMI	Body Fat, %
A (n = 5)	13.0 ± 0	165.6 ± 4.36	49.4 ± 2.27	18.0 ± 0.61	12.3 ± 1.84
B (n = 5)	13.0 ± 0.71	157 ± 6.3	45.4 ± 6.69	18.1 ± 2.03	13.3 ± 3.24
C (n = 5)	12.8 ± 0.7	155.8 ± 9.9	42.14 ± 6.29	17.3 ± 0.96	11.5 ± 2.36
Average	12.9 ± 0.8	159.4 ± 8.0	45.66 ± 5.91	17.9 ± 1.34	13.3 ± 2.48
F test; p value	F = 2.7; p > 0.05	F = 2.8; p > 0.05	F = 2.2; p > 0.05	F = 0.94; p > 0.05	F = 0.61; p > 0.05

sports results and plan the trends of athlete training. Another important feature is the interaction of indices between training and sport performance (Banister et al., 1999; Edelmann-Nusser, et al., 2002; Avalos et al., 2003; Bügner, 2005; Hellard et al., 2006). J. Perl (2001, 2003, 2004) called this interaction a *Metamodel* – the theoretical interaction of training and sport performance – when we need to find an optimal model of athlete training which would allow achieving the highest level of sport performance.

Most research of this kind has been carried out in swimming (Edelmann-Nusser et al., 2002; Avalos et al., 2003; Bügner, 2005; Hellard et al., 2006) and track-and-field athletics (Banister et al., 1999). The adaptation to physical loads, intensity of training loads and competitive activities of the rhythmic gymnastics has not yet been studied.

Rhythmic gymnastics is a sport which requires early selection of athletes (Лисицкая и др., 1982; Balyi, 2001; Карпенко, 2003; Balyi, Hamilton, 2004), intensive training in the periods of childhood and adolescence (Jastrejembskaia, Titov, 1999; Карпенко, 2003) and early termination of the sports career (Стамбулова, 1999). The trends in the changes of training high performance athletes (Balyi, 2001; Balyi, Hamilton, 2004), specific features of the developments of rhythmic gymnastics (Krug, 1996; Jastrejembskaia, Titov, 1999; Knoll et al., 2000; Медведева, 2001; Карпенко, 2003), as well as the upturn of sports results motivate us to look for new, scientifically grounded sports technologies, methods and forms of training. That is why the **aim** of this study was to determine the impact of specific training on sport performance of 13–14-year-old athletes in rhythmic gymnastics.

RESEARCH METHODS

Subjects and experiment design. The research involved the training of 13–14-year-old athletes (n = 15) in rhythmic gymnastics from the National and Kaunas city teams (Lithuania) (Table 1). The experiment resulted in modeling three (A, B, and C) different training programs (5 gymnasts in each training program) and establishing the structure of the content of the training programs for the whole macrocycle, as well as athletes' sport performance. The training loads protocols registered the time for choreography, element learning, competitive routines and athletic training in each training session (Лисицкая и др., 1982; Jastrjembskaia, Titov, 1999).

The efficacy of the training programs was established registering the realization of competitive activities under competitive conditions, according to the number of points received by the gymnast of each training program, and according to the place won (the points awarded in the descending order). Participation of gymnasts in competitions was different because not all of them succeeded in winning the right to participate in more important competitions – national and international.

Research hypothesis (H_0) was that different training programs (Tables 2 and 3) would have the same impact on sports performance. The alternative hypothesis was that different training programs would have different impact on sport performance (H_1). Independent variables were the duration, content, volume, intensity of training loads, and the dependent variable was athletes' sport performance.

The following **research methods** were used in this research:

- **Anthropometry.** The values of height in the standing position and body mass components (body mass, body mass index BMI, subcutaneous body fat layer in percent (%), and kilograms (kg)) (TANITA BODY ANALYSER TBF-300) were taken.
- **Physical fitness.** Athletic fitness of female athletes was estimated applying tests of flexibility (tests of “bridge” and “splits”),

complex abilities of flexibility and balance (test of "leg keeping"), muscular endurance (push–ups, sit-ups and lifting legs), specific endurance (test of "jumping into rope with double turns"), coordination abilities ("10 seconds running into the rope") and explosive strength (standing long jump on both feet). Research presented absolute values of estimation of movement abilities, and the values estimated in points. The integral index estimating athletic fitness was received summing up the points of each test (Лисицкая и др., 1982; Jetrejambskaja, Titov, 1999; Говорова, Плешкань, 2001; Карпенко, 2003).

- Changes in gymnasts' **technical fitness** were registered during competitions according to the declared and realized coefficients of technical fitness – Difficult values and Artistic values (Abbruzini, 2004).

Methods of mathematical statistics. In order to compare the data the means ($\bar{x}$) and standard deviations (SD) were calculated. One-way analysis of variance – ANOVA (generalizing Student criterion for several independent samples was used to evaluate the differences and the reliability of value differences. The following reliability levels of statistical conclusions were used: $p < 0.05$ – reliable; $p < 0.01$ – very reliable; $p < 0.001$ – absolutely reliable conclusion. Causal relations were determined applying correlation analysis (Pearson's correlation coefficient r). The significance of training and fitness factors was established by factor analysis (principal factor analysis – communalities = multiple r^2). All calculations were performed using computer programs MS Excel and STATISTICA. Experimental data were described using 44 variables, 43 of which were the aspects of training and fitness (X) and one was the final indicator of the efficacy of competitive activities (the mean of the points achieved by each gymnast) – Y. The principal factor analysis (communalities = r squares) was performed to estimate the interaction of the structure, the content and the volume of the complicated training process and fitness.

RESEARCH RESULTS

Training. Training athletes in three training programs differed – their training loads were significantly different ($p < 0.01$) – from 10.28 to 12.91 hours a week, as well as the indices of the training days – from 5.43 to 4.17 days a week (Table 2). 13–14-year-old athletes in rhythmic gymnastics in the most effective training program (A) in specific training in our experiment received the highest loads (283 days of training in the macro-cycle, 5.44 training sessions a week on average, all in all 674 hours of training, averagely 13.0 hours a week). Training parameters – training loads and content (Table 3) were different in the course of the whole macro-cycle and in different training periods ($p < 0.05$).

The percentage structure of the training content did not differ much in each training period. Statistically significant differences ($p < 0.05$) were found in the duration of mastering elements ($p < 0.02$) in the most effective training program (A), time for athletic training in program C ($p < 0.05$). The percentage structure of the training loads in program C did not differ statistically significantly ($p > 0.05$).

Sport performance. The most effective training program was A: 533 (points) with choreographic training dominating in it (35.8%).

Table 2. **Training loads of different training programs of 13–14-year-old athletes in rhythmic gymnastics**

Parameters of training loads	Training groups ($\bar{x}$ ± SD)			Mean ($\bar{x}$ ± SD)	Fisher's criterion, p level
	A	B	C		
Number of training sessions a year	283	213	258	225.66 ± 34.6	
Number of macro-cycle hours	674	519	593	591.33 ± 76.0	
Number of training sessions a week	5.4 ± 1.39	4.2 ± 1.09	5.3 ± 0.85	5.0 ± 1.26	F = 16.74; $p < 0.001$
Number of hours a week	13.0 ± 3.29	10.3 ± 2.94	11.9 ± 2.75	11.7 ± 3.19	F = 8.98; $p < 0.001$
Number of competitions a year (from – to, and average)	9–14 12.2 ± 2.05	10–14 12.2 ± 1.79	10–14 12.2 ± 1.79	9–14 12.2±1.74	
Number of competition days	23 days (duration of loads of competition days ~3 h)				

Table 3. **Content (%) of training loads of different training programs of 13–14-year-old athletes in rhythmic gymnastics**

Content of training loads	Training groups ($\bar{x}$ ± SD)			Mean ($\bar{x}$ ± SD)	Fisher's criterion, p level
	A	B	C		
Choreography	29.32 ± 7.09	31.59 ± 7.86	**33.93 ± 5.84**	31.56 ± 7.19	**F = 5.06; p < 0.01**
Elements	20.79 ± 6.96	**38.67 ± 11.13**	22.82 ± 4.58	27.31 ± 11.30	**F = 67.78; p < 0.001**
Competition routines	**33.57 ± 12.04**	16.56 ± 9.15	19.56 ± 6.52	23.86 ± 12.43	**F = 48.05; p < 0.001**
Athletic training	14.40 ± 5.00	11.62 ± 8.26	21.02 ± 5.02	15.65 ± 7.34	**F = 26.80; p < 0.001**

The least effective program was B (240 points), where each gymnast collected 48.0 points on average. The integral index of gymnasts' athletic fitness was different at the beginning of the season ($p < 0.05$). The differences between the muscular test results diminished, too (evaluation of "press-ups" in times and points, "sit–ups" in points), but there appeared a difference between the indices of coordination abilities ("10 seconds running into the rope" in points) ($p < 0.05$). Though there were positive alterations in the indices of all movement abilities, no statistically significant differences were established between the indices of athletic fitness in different training groups before the experiment and after it ($p > 0.05$).

At the beginning of the season ($F = 5.56$; $p < 0.001$) and at the end of it ($F = 9.06$; $p < 0.001$) the realization of the body movement technique performing routines with different tools was different (Table 4). Such tendency remained after the experiment.

Coefficients of different routines with tools did not differ significantly ($p > 0.05$) (from 4.18 to 3.52). In different training programs indices of movements with tools before the season ($F = 9.93$; $p < 0.001$) and at the end of the season ($F = 14.32$; $p < 0.001$) were different. The average coefficients of difficulty of technique were the lowest in training program C (2.09 ± 0.60), and the highest – in training program A (3.03 ± 0.94). At the end of

Table 4. **Body movement technique coefficients of difficulty with different tools in different rhythmic gymnastics training programs for 13–14-year-old athletes**

Before experiment (at the beginning of the season) ($\bar{x}$ ± SD)				
Training Progamm / Tools	**A (n = 5)**	**B (n = 5)**	**C (n = 5)**	**Average**
Rope	4.21 ± 0.46	2.81 ± 0.81	3.24 ± 0.60	3.32 ± 0.89
Ball	3.70 ± 0.41	3.41 ± 0.34	3.56 ± 0.32	3.58 ± 0.35
Clubs	4.02 ± 0.66	2.73 ± 0.85	3.25 ± 0.26	3.44 ± 0.78
Ribon	3.07 ± 0.94	1.99 ± 0.80	2.58 ±0.68	2.72 ± 0.92
The average coefficients of difficulty	**3.61 ± 0.83**	**2.57 ± 0.89**	**3.18 ± 0.57**	**3.19 ± 0.86 F = 4.09; p < 0.001**
After experiment (at the end of the season) ($\bar{x}$ ± SD)				
Training Progamm / Tools	**A (n = 5)**	**B (n = 5)**	**C (n = 5)**	**Average**
Rope	3.34 ± 0.66	2.93 ± 0.35	3.16 ± 0.70	3.14 ± 0.60
Hoop	3.23 ± 0.75	2.77 ± 0.67	3.15 ± 0.74	2.95 ± 0.73
Clubs	3.20 ± 0.62	3.18 ± 0.16	3.26 ± 0.21	2.93 ± 0.72
Ribbon	3.35 ± 0.57	2.46 ± 0.91	3.0 ± 0.59	2.84 ± 0.78
The average coefficients of difficulty	**3.23 ± 0.64**	**2.60 ± 0.71**	**3.16 ± 0.57**	**2.97 ± 0.70 F = 3.41; p < 0.001**

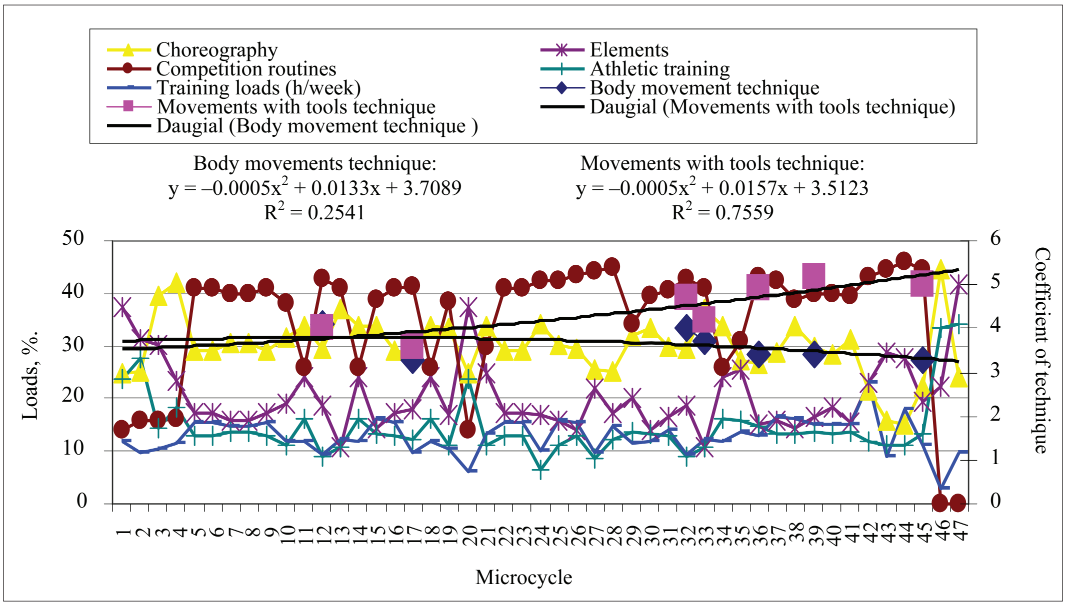


Figure. **Changes in the volume of training loads (%) and complexity of the content and technique in the most effective training program in the experiment for 13–14-year-old athletes in rhythmic gymnastics during the macro-cycle**

the season the coefficient of movement with tools technique ranged form 2.33 (ribbon) to 3.36 (clubs). At the end on the season the highest coefficients of difficulty were demonstrated by athletes in training program A (3.03 ± 0.94) and C (3.16 ± 1.02).

The subjective evaluations of ones own sport performance (self-confidence before the competition) between various groups were not statistically significantly different ($p > 0.05$).

Interaction of training and sport performance. In the most effective training program correlations between body movement techniques and program training loads were $r = -0.514$; polynomial interdependence: $y = -0.0003 \times 2 + 0.0008x + 0.0369$; $r^2 = 0.4553$; and between movement with tools techniques and training loads: $r = 0.658$; and polynomial interdependence: $y = 0.0006 \times 2 - 0.0186x + 0.0894$; $r^2 = 0.4069$. Effective training of athletes in program B (11–12 and 12–13 years of age) was determined by the dominance of choreographic training. At this period of training the program was distinguished by the time for the mastering of competitive routines (33.57% on average).

The most effective training program, which included choreographic training (30.3%), element mastering (19.6%), mastering of competitive routines (37.3%) and athletic training (12.8%) since the 17th micro-cycle, improved the indices of technical fitness of 13–14-year-old moderate sport performance athletes in rhythmic gymnastics: body movement technique (21.1%), tool technique (30.5%) (Figure). The achieved level of performance of movements with tools (6.35%) was improved in 14 weeks, in the training program of the following structure: 27.2% of choreographic training, 21.95% of element mastering, 40.3% of mastering competitive routines, and 13.1% of athletic training. The stable level of tool technique was maintained till the end of the season (7 micro-cycles), but body movement technique almost did not change and even diminished till 21.1% in 7 micro-cycles.

In the most effective training program the reduced time for choreography (in %) affected the changes in training and sport performance (body movements and movements with tools) – the changes in the movement techniques can be explained by the following slight positive dependence: 20% ($y = 0.0001 \times 2 + 0.0002x - 0.0197$; $r^2 = 0.2039$), and in the movement with tools technique – negative dependence of 13% ($y = -0.0003 \times 2 + 0.0123x - 0.0782$; $r^2 = 0.1398$).

DISCUSSION

Analysis of interaction of training and sport performance comparing *internal* (indices of moderately mastered body movements and movements with tools) and *external* (training loads in hours per week) (Mester, Perl, 2000) factors partly differs from what other scientists (Hartmann, Mester, 2000) suggest, that from the standpoint of a macro-cycle the interaction between the indices of training and sport performance is neither significant nor effective. According to some researchers (Perl, 2004; Bügner, 2005), the contradictions in the management of training are natural, because due to the inner changes of an athlete the same training loads can produce different sport performance.

Adverse changes in the indices of body technique (the indices of technique in the most effective training program decreased from coefficient 4.1 to coefficient 3.3) at the end of the season confirm the supposition raised in the previous stage of the research that the increase in difficulty of body technique stabilizes – only the number of mistakes becomes less, but movements with tools are practiced and improved further on. This confirms what other researchers (Карпенко, 2003) suggest: the best age for developing coordination abilities is up to 12–13 years.

Researchers (Лисицкая и др., 1982; Jastrjembskaia, Titov, 1999; Apatow, 2001; Карпенко, 2003) suggest that *choreographic training* should be sufficient in all periods of training, but it should become more difficult, more choreographic elements should be performed without support, in all directions and with frequent turns (Лисицкая и др., 1982; Jastrjembskaia, Titov, 1999; Wolf–Cvitak et al., 2002; Карпенко, 2003; Wolf–Cvitak, 2004). It should be noted that elite gymnasts spend 45 minutes six times a week for choreography (Apatow, 2001; Карпенко, 2003). Our training programs contained 52 minutes 4.4 times a week (program A). Our research data suggest that in this period of training the influence of choreographic training on body movement and movement with tools technique is not so great. It means that more time on choreographic training should have been spent in the earlier periods of training.

In co-coordination sports training loads are presented according to the number of elements and combinations (Аркаев, Сучилин, 1997; Смолевский, Гавердовский, 1999; Медведева, 2002), but such system of registering training loads is more suitable for training management in artistic gymnastics. In this period of training in rhythmic gymnastics the value competitive activities much depends on the individual style of a gymnast, her artistry and ways of expression (Jastrejembskaia, Titov, 1999; Карпенко, 2003). Those qualities can be demonstrated only after having mastered the competitive routines. So, in the period of individualized training the importance of mastering elements for technical fitness diminished. As researchers suggest (Меканцишвили, 1991; Jastrejembskaia, Titov, 1999; Карпенко, 2003; Wolf–Cvitak, 2004), much time should be spent for competitive routines, and separate elements and parts of those routines should be practiced together with them.

After grouping the results of different factors (training and sports performance, sport performance, training), we can state that the most important factors for good results are explosive strength, strength endurance, coordination and the integral index of athletic fitness. Techniques with tools (skipping rope, ribbon, ball and average technique of all tools) were also of great importance. At this period of training the significance of training factor was not so great, thus, the significance of sports performance and technical fitness could have been conditioned by training loads applied in the earlier periods.

CONCLUSIONS AND PERSPECTIVES

In the period of individual training of 13–14-year-old athletes in rhythmic gymnastics time for mastering competitive routines ($r = 0.945$) and integral training ($r = 0.861$) became more significant for the efficacy of athletes' sports performance. The indices of movement with different tools technique became more significant ($r = 0.708 \div 0.805$), and the indices of difficulty of body movement technique remained stable. The most important factors influencing sports performance were explosive strength ($r = 0.819$), strength endurance ($r = 0.794$), coordination ($r = 0.756$), and the total integral index of athletic fitness ($r = 0.840$).

REFERENCES

Abruzzini, E. (2004). *Code of Points in Rhythmic Gymnastics*. FIG. [01 03 2007]. Internet link: www.fig–gymnastics.com

Apatow, S. (2001). *Why Eastern Bloc Countries Dominated the Gymnastics Field in Sydney.* [23 05 2005]. Internet link: www.education.ed.ac.uk/gym/papers.sa.html

Avalos, M., Hellard, P., Chatard, J. C. (2003). Modeling the training–performance relationship using a mixed model in elite swimmers. *Medicine and Science in Sports and Exercise*, 26, 217–238.

Balyi, I., Hamilton, A. (2004). *Long–term Athlete Development: Trainability in Childhood and Adolescence Windows of Opportunity, Optimal Trainability*. Victoria: National Coaching Institute British Columbia & Training and Performance Ltd.

Balyi, I. (2001). Sport System Building and Long-term athlete development in British Columbia, Canada. *Sports Medicine Council of British Columbia*. [10 05 2010]. Internet link: www.sportdevelopment.org.uk

Banister, E. W., Carter, J. B., Zarkadas, P. C. (1999). Training theory and taper: Validation in triathlon athletes. *European Journal of Applied Physiology*, 79, 182–191.

Bügner, J. (2005). *Nichtlineare Methoden in der Trainingwissenchaftlichen Diagnostik: Mit Untersuchungen aus dem Schwimmsport*: *Doctor Dissertation.* Potsdam Univeristät.

Edelmann-Nusser, J., Hohmann, A., Henneberg, B. (2002). Modeling and prediction of competitive performance in swimming upon neural networks. *European Journal of Sport Science*, 2 (2), 1–10.

Hartmann, U., Mester, J. (2000). Training and overtraining markers in selected sport events. *Medicine and Science in Sports and Exercise,* 32, 209–215.

Hellard, P., Avalos, M., Lacoste, L. et al. (2006). Assessing the limitations of the Banister model in monitoring training. *Journal of Sport Sciences*, 24 (5), 509–520.

Jastrejembskaia, N., Titov, Y. (1999). *Rhythmic Gymnastics*. Champaign: Human Kinetics.

Knoll, K., Knoll, K., Kothe, T. (2000). Grenzen der Leistungsfahigkeit des Menschen in den technisch-kompositorischen Sportarten. *Leistungssport*, 1, 33–38.

Krug, J. (1996). *Entwiklungstendenzen der Trainings – und Wetkampfsysteme in den technisch – kompositorischen Sportarten. Zeitschrift für Angewedte Trainingswiseenschaft*. [10 05 2009]. Internet link: http://iat.uni-leizig.de/iat/zeitschrift/hinweis.htm

Mester, J., Perl, J. (2000). Grenzen der Anpassungs – und Leistungsfahigkeit des Menchen aus systematischer Sicht: Zeitreihenanalyse und ein informatisches Metamodell zur Untersuchung physologischer Adaptionsprozesse. *Leistungssport*, 1, 43–51.

Perl, J. (2004). Modelling Dynamics Systems – basic aspects and applications to performance analysis. *International Journal of Sport Science in Sport,* 3 (2), 19–28.

Perl, J. (2003). *On the Long-Term Behavior of the Performance-Potential-Metamodel PerPot*. [2006 05 20]. Internet link: http://www.informatic.uni-mainz.de/dycon/

Perl, J. (2001). Per-Pot: A Metamodel for Simulation of Load Performance Interaction. *European Journal of Sport Science (EJSS)*, 1 (2), 13.

Torrents, C., Perl, J., Schöllhorn, W., Balague, N. (2001). Quantitative and qualitative load optimization in strength training with the Per Pot Metamodel. In J. Mester, G. King, H. Strüder, E. Tsolakidis, A. Osterburg, (Eds.), *Proceedings of the 6th Annual Congress of the European College of Sport Science Perspectives and Profiles* (pp. 1059).

Wolf-Cvitak, J., Griič-Zubčevič, N., Maric, Ž. (2002). Influence of training of rhytmic gymnastics fundamentals on certain motor abilities in girls 8–9 years of age. *Kinesiology*, 34, 61–72.

Wolf-Cvitak J. (2004). *Ritmička Gimnastika*. Zagreb: Kugler.

Аркаев, Я. Л., Сучилин, Н. Г. (1997). Методологические основы современной системы подготовки гимнастов высшего класса. *Теория и практика физической культуры*, 11, 17–25.

Говорова, М. А., Плешкань, А. В. (2001). *Специальная физическая подготовка юных спортсменок высокой квалификации в художественной гимнастике*. Москва.

Карпенко, Л. А. (2003). *Художественая гимнастика*. Москва: ФИС.

Лисицкая, Т. С., Бирюк, Е. В., Новик, М. Г., Батаен, В. Г. (1982). *Художественная гимнастика*. Москва: ФИС.

Медведева, И. М. (2001). Модель целевой соревновательной деятельности в видах спорта со сложнокординационной структурой движений. *Педагогіка, психолоія та мед.: біол. пробл. физ. виховання і спорту.* Харьков (сс. 12). [15 03 2009]. Internet link: http://www.nbuv.gov.ua/articles/2001/12awrsbp.zip

Медведева, И. М. (2002). Построение програм микро– и мезоциклов подготовки квалифицированных фигуристов. Педагогіка, психолоія та мед.: біол. пробл. физ. виховання і спорту. Харьков. С. 10. [15 11 2010]. Internet link: http://www.nbuv.gov.ua/articles/2002/10awrsbp.zip

Меканцишвили, С. А. (1991). *Программированние и нормированние тренировочных нагрузок при подготовке груповых упражнений в художественной гимнастике*: *автореферат дисс.* Тбилиси. С. 24.

Смолевский, В. М., Гавердовский, Ю. К. (1999). *Спортивная гимнастика*. Киев: Олимпийская литература.

Стамбулова, В. (1999). *Психология спортивной карьеры*. Санкт Петербург: Центр карьеры.

Чедураев, В. С. (1997). Научно методическое обеспечение подготовки сборных команд страны по спортивной гимнастике. *Теория и практика физической культуры*, 11, 44–46.

MENINĖS GIMNASTIKOS SPORTININKIŲ (13–14 METŲ) RENGIMO IR PARENGTUMO OPTIMIZAVIMAS

Renata Rutkauskaitė, Antanas Skarbalius
Lietuvos kūno kultūros akademija, Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Sportininkų ugdymo veiksmingumas priklauso nuo kryptingo rengimo vyksmo tam tikrais sportininkų rengimo etapais, valdymo, individualios sportininko adaptacijos prie pratybų ir varžybų krūvių.

Tikslas: išsiaiškinti specifinio rengimo poveikį 13–14 metų meninės gimnastikos sportininkių parengtumo optimizavimui.

Metodai. Eksperimento metu buvo modeliuota trijų skirtingų rengimo programų rengimo struktūra ir registruotas sportininkių parengtumas (atletinis, techninis ir psichinis). Krūvių registravimo protokoluose buvo registruojamas choreografijai, elementų mokymuisi, varžybiniams pratimams bei atletiniam rengimui skirtas laikas per kiekvienas pratybas. Rengimo programų veiksmingumas nustatytas registruojant varžybinės veiklos realizavimą varžybinėmis sąlygomis pagal kiekvienos rengimo programos gimnastės gaunamus taškus, pagal kiekvieną iškovotą vietą (nustatytą taškų skyrimą mažėjančia tvarka).

Rezultatai. Skirtingų programų sportininkės treniravosi nevienodai – reikšmingai skyrėsi taikomų krūvių (nuo 10,28 iki 12,91 h per savaitę) ($p < 0,001$), pratybų dienų rodikliai (nuo 5,43 iki 4,17 dienų per savaitę) ir sportininkių rengimo turinys. Statistiškai reikšmingai skyrėsi staigiosios jėgos ir jėgos ištvermės, specifinės ištvermės, koordinacijos judamųjų gebėjimų rodikliai ir atletinio parengtumo integralusis rodiklis, išreikštas balais ($p < 0,05$). Veiksmingiausioje rengimo programoje vyravo choreografinis regimas (35,8%). Kūno veiksmų ir veiksmų su įrankiais technikos realizavimas įvairiose rengimo programose sezono pradžioje ir pabagigoje buvo skirtingas ($p < 0,05$).

Aptarimas ir išvados. Sportinių rezultatų siekimo etapu išryškėjo 13–14 metų meninės gimnastikos sportininkių varžybiniams pratimams tobulinti skirto laiko ir integraliojo rengimo reikšmė sportininkių varžybinės veiklos veiksmingumui. Pastebėta veiksmų su atskirais įrankiais technikos reikšmė, o kūno judesių technikos sudėtingumo rodikliai nusistovėjo. Svarbiausi veiksniai, nusakantys geriausius rezultatus, yra staigioji jėga, jėgos ištvermė, koordinacija ir susumuotas integralusis atletinio parengtumo rodiklis.

Raktažodžiai: meninė gimnastika, rengimas, parengtumas.

Gauta 2011 m. liepos 23 d.
Received on July 23, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Renata Rutkauskaitė**
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 674 09104
E-mail r.rutkauskaite@lkka.lt

ECCENTRICALLY-INDUCED FATIGUE IN VOLUNTARY MUSCLE PERFORMANCE: THE EFFECT OF MUSCLE LENGTH AND CONTRACTION TYPE

Albertas Skurvydas, Marius Brazaitis, Sigitas Kamandulis, Dalia Mickevičienė, Diana Karanauskienė
Lithuanian Academy of Physical Education, Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. We hypothesized that eccentric exercise (EE) would induce muscle fatigue and damage, which are dependent not only on muscle length tested but and on contraction type (eccentric vs. concentric vs. isometric) as well.

Research aim was to test the hypothesis.

Research methods. Healthy untrained men (mean ± SD: age = 24.8 ± 3.7 years, n = 10) performed 10 series of 12 repetitions of eccentric knee contractions at 160 deg/s. The maximal voluntary isometric contraction force (MVC) of the quadriceps muscle, the maximal rate of torque development (RTD) and isokinetic torque at 30 deg/s were established before and after EE. All measures were performed at different knee angles. Besides, the EMG of the quadriceps muscle was measured.

Research results showed a significant change in absolute values of RTD after EE (before EE: 3695 ± 803 N·m/s and 2360 ± 695 N·m/s at SL and LL respectively; after EE: 2574 ± 843 N·m/s and 1517 ± 476 N·m/s at SL and LL respectively). A significant difference between EMG (rms) in MVC was found after EE at LL and SL, i. e. in v.lateralis 0.32 ± 0.12 mV and 0.24 ± 0.1 mV and in r.femoris 0.25 ± 0.11 mV and 0.17 ± 0.07 mV respectively. All criteria of voluntary performance changed significantly after EE except for RTD, i.e. it increased after EE.

Discussion and conclusions. We observed more changes in isokinetic torque at shorter muscle length after eccentric exercise-induced muscle fatigue and damage. The changes in MVC and RTD after eccentric exercise did not depend on the length of the muscle tested. Besides, relative RTD did not change after exercise.

Keywords: eccentric, concentric and isometric contraction; muscle fatigue and damage; muscle length, muscle force; rate of muscle torque development

INTRODUCTION

The well documented symptoms of exercise-induced muscle damage (EIMD) include prolonged impairment of muscle function as measured in voluntary and electrically-induced contractions (Warren et al., 1999; Byrne et al., 2004; Skurvydas et al., 2006). In addition, there is strong evidence for low frequency fatigue (LFF) (Skurvydas et al., 2006), protein leakage from injured muscle fibres, acute inflammation reaction and delayed-onset muscle soreness, stiffness and swelling (Chapman et al., 2008; Skurvydas et al., 2008). It is generally agreed that there are two prominent signs of damage in the muscle immediately after it has been subjected to a series of eccentric contractions. These are the presence of disrupted force-bearing structures and damage to excitation-contraction coupling system (Warren et al., 1999; Proske, Morgan, 2001).

It has been established that muscle damaging exercise decreases muscle isometric, concentric and eccentric contraction force (Warren et al., 1999; Michaut et al., 2003; Byrne et al., 2004; Skurvydas et al., 2006; Hubal et al., 2008), rightward shift in the optimum joint angle for voluntary isometric (Proske, Morgan, 2001; Philipou et al., 2004; McHugh, Tetro, 2003; Chen et al., 2007) as well concentric strength (Yeung S. S., Yeung E. W., 2008), impairment in voluntary activation more at shorter muscle length (Prasartwuth et al., 2006). The following issues, however, have not been cleared up, yet, namely: 1) what are length-dependent changes in quadriceps muscle torque during isometric as well as in concentric contraction, 2) are there differences between changes in maximal voluntary isometric contraction torque (MVC) and rate of torque development (RTD), what is the relationship between the changes in different muscle mechanical characteristics after muscle damaging eccentric exercise? The primary aim of the present study was to clarify these issues.

RESEARCH METHODS

Subjects. Healthy untrained men (mean ± SD: age = 24.8 ± 3.7 years, body weight = 78.2 4.7 kg, height = 179.9 ± 3.6 cm, n = 10) took part in this study. The untrained subjects were physically active but did not take part in any formal physical exercise or sport program. They had not been involved in any specific fitness training programs during recent years. Each subject read and signed written informed consent form consistent with the principles outlined in the Declaration of Helsinki. The Ethics Committee of Kaunas University of Medicine approved this study.

Muscle damaging eccentric exercise (EE). The subjects performed EE: 10 series of 12 eccentric repetitions with maximal intensity at the angle velocity of 160 deg/s (the range of knee angle was from 150 to 70 deg; full knee extension – 180 deg). Time period between series was 1 min. Subjects were asked to perform every repetition with maximal effort. The first and the last repetitions in each series were omitted from analysis. The average peak eccentric torque (ET) in a each series was used to calculate the fatigue index (FI) as follows: FI = (1st series ET – 10th series ET) / 1st series ET × 100%.

Isometric torque. The isometric torque of knee extensor muscles was measured using an isokinetic dynamometer (System 3; *Biodex Medical Systems, Shiley*, New York). The sensitivity of the Biodex System 3 in torque measurements is ± 1.36 N·m. The subjects sat upright in the dynamometer chair with the knee joint positioned at 130 and 90 degrees angle. The subjects were ask to perform maximal voluntary contraction force (MVC) as fast as possible at the knee angles of 90 and 130 degrees, for long (LL) and short (SL) muscle length, respectively. The subjects were asked to develop MVC and hold it about 4–5 s. MVC was tested three times in both angles. In all cases muscle torque registrations at different angles were taken randomly. The rest interval between MVC measurements was 1 min. Fatigue index (FI) in percent was calculated according to the formula: (Torque value before EE – Value after EE) / Value before EE/100 per cent. The peak rate of torque development (RTD) was calculated. RTD was defined as the maximal slope of the force time curve (Dforce / Dtime).

Isokinetic torque (IT) measurement. The subjects were asked to perform three continuous repetitions of knee extension with maximal intensity at angle velocity 30 deg/s. The angle range was from 70 to 150 deg (full knee extension – 180 deg). The knee flexion was not required to perform (knee was set passively at start position). Isokinetic torque (IT) (average of three repetitions) at different angles, i. e. at 80, 90, 100, 110, 120 and 130 degrees was measured. Besides, the optimal degree which gave optimal isokinetic torque (ITopt) was established.

Electromyography. This study used a portable Biometric Datalog system for the transportability to the older adult participants who resided in an independent senior-living community setting. Four channels were used: one for the ground and three for the EMG sensors. The high-pass filter was set at 20 Hz and the low-pass filter was set at 450 Hz. The EMG data were recorded and stored with the Biometrics Datalog programmable data acquisition unit. This portable unit allowed us to collect sampled digitized data from the reusable EMG sensors. The sampling rate was 1000 samples/s. The SX230 surface EMG sensor is used with DataLOG to collect data of muscle electrical activity. Bipolar surface electrodes (diameter 10 mm, center to center distance 20 mm) were placed over the vastus medialis, vastus lateralis and rectus femoris of the right leg. The longitudinal axes of the electrodes were in line with the presumed direction of the underlying muscle fibers. All electrode positions were carefully determined and marked to ensure identical pre- and post-exercise recording sites. EMG electrodes were directly connected to custom built differential pre-amplifiers (gain 1000, input impedance of 10 MΩ, common mode rejection 96 dB at 60 Hz) and taped to the skin. Input noise level was less than 5 μV. Root mean square (rms) EMG amplitudes were determined for the distinct time intervals 0–100 ms during explosive contraction as well as during maximal voluntary contraction at 2–3 s.

Rectal and muscle temperatures measurement. Rectal (T_{re}) and muscle temperatures (T_{mu}) in 6 subjects were measured before and after EE. T_{re} was measured with a thermocouple (*Rectal Probe, Ellab, Hvidovre*, Denmark) inserted to a depth of 12 cm past the anal sphincter. The intramuscular temperature was measured with a needle microprobe (*MKA, Ellab, Hvidovre*, Denmark) inserted into 3-cm depth under the skin covering m. vastus lateralis of the left leg.

Plasma creatine kinase (CK) activity. Approximately 5 ml of blood was drawn from *vena cubiti media* of the arm at each measurement time point (before exercise as well as 48 h after exercise). Plasma samples were pipetted into microcentrifuge tubes and stored in a –20^{o}C freezer until analysis. Plasma CK (IU/L) activity was determined by using automatic biochemical analyzer "Monarch" (*Instrumentation Laboratory SpA*, USA-Italy).

Muscle soreness. Muscle soreness was reported subjectively using a visual analogue scale of 0 to 10, where 0 represented "no pain" and 10 represented "intolerably intense pain". These muscle soreness evaluation methods have also been used in our previous research (Skurvydas, et al. 2006, 2008). The participants were required to indicate the severity of soreness in their quadriceps in response to muscle compression, as well as when standing up and walking at the start of each daily session.

Experimental protocol. Three-five days before the experiment thesubjects were introduced to different tasks of voluntary performance. After measuring CK in the blood, T_{re} and T_{mu} the subject was seated in the experimental chair and after 5 min, MVC was tested. About 3 min later three IT at 30 deg/s were performed. About 3 min later the EE was undertaken. Two min after EE registering of the same contractile properties was started (they were registered 2–10 min). Besides, at 24 h and 48 h after EE muscle soreness as well as CK activity at 48 h after EE was determined.

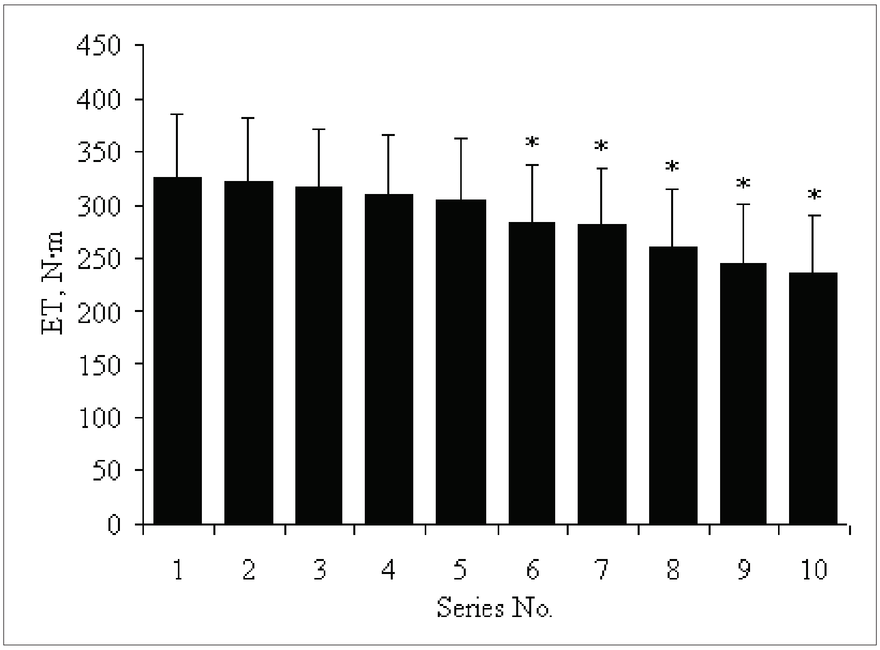
Data and statistical analysis. Descriptive data are presented as means ± SD. Significant effects were found, post hoc testing was performed applying paired t-tests with a Bonferroni correction for multiple comparisons. The level of significance was set at 0.05. In order to evaluate the relationship between changes in different indicators of voluntary induced muscle performance after EE Pearson's correlation coefficient was established. Based on alpha level of 0.01, sample size (n = 11) standard deviations and average level before and after eccentric exercise statistical power was calculated for all mechanical indicators. Statistical power in all cases was more than 80 per cent.

RESEARCH RESULTS

Eccentric torque during exercise. The eccentric torque (ET) decreased by 27.9 ± 9.9% ($p < 0.001$) at the end of exercise (Figure 1). The T_{re} increased from 37.1 ± 0.3° C degrees to 38.2 ± 0.2° C degrees ($p < 0.01$), T_{mu} from 36.9 ± 0.4° C degrees to 39.5 ± 0.3° C degrees ($p < 0.001$) after exercise. Within 24 h – 48 h after EE the subjects felt an acute muscle pain (5–6 points). The plasma CK activity 48 h after EE had increased up to 680.4 ± 594.2 IU/L ($p < 0.01$, compared to before level, 119.7 ± 48.7 IU/L).

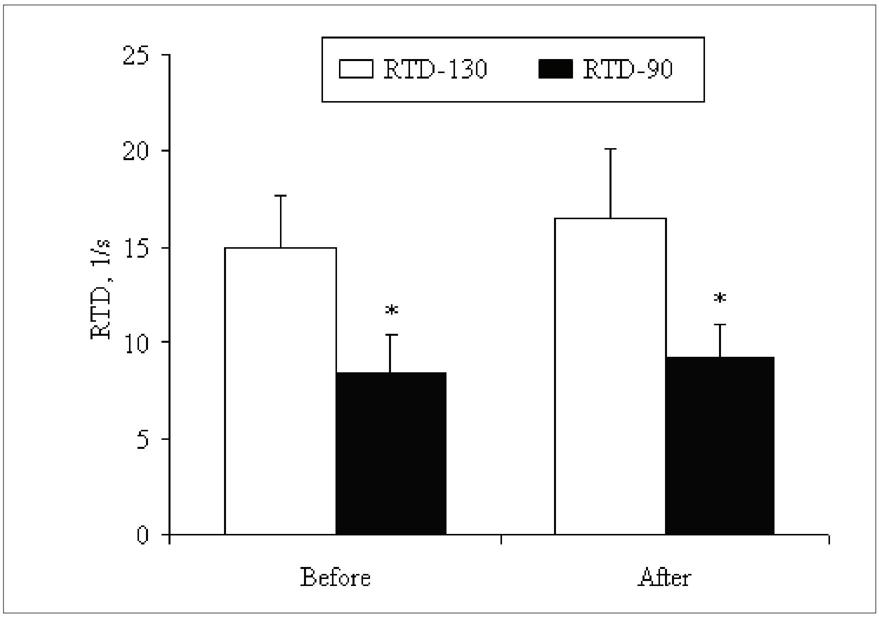
The muscle length and contraction type effect on changes in muscle voluntary performance after EE. MVC was significantly greater at LL compared to SL before exercise (280.3 ± 47.5 N·m and 246.4 ± 33.1 N·m, respectively), but for relative RTD the reverse was true (Figure 2). However, there was a significant change in absolute values of RTD after EE (before EE: 3695 ± 803 N·m/s and 2360 ± 695 N·m/s at SL and LL respectively; after EE: 2574 ± 843 N·m/s and 1517 ± 476 N·m/s at SL and LL respectively). Before EE it was only in *v. lateralis* muscle that EMG (rms) was significantly ($p < 0.01$) greater during 100 ms at SL compared to LL, i. e. 0.26 ± 0.13 mV and 0.15 ± 0.06 mV respectively. There was a significant difference between EMG (rms) in MVC at LL and SL, i. e. in *v. lateralis* 0.32 ± 0.12 mV and 0.24 ± 0.1 mV and in *r. femoris* 0.25 ± 0.11 mV and 0.17 ± 0.07 mV respectively.

Figure 1. **The changes in eccentric torque (ET) during 10 series of 12 eccentric contractions at 160 deg/s**



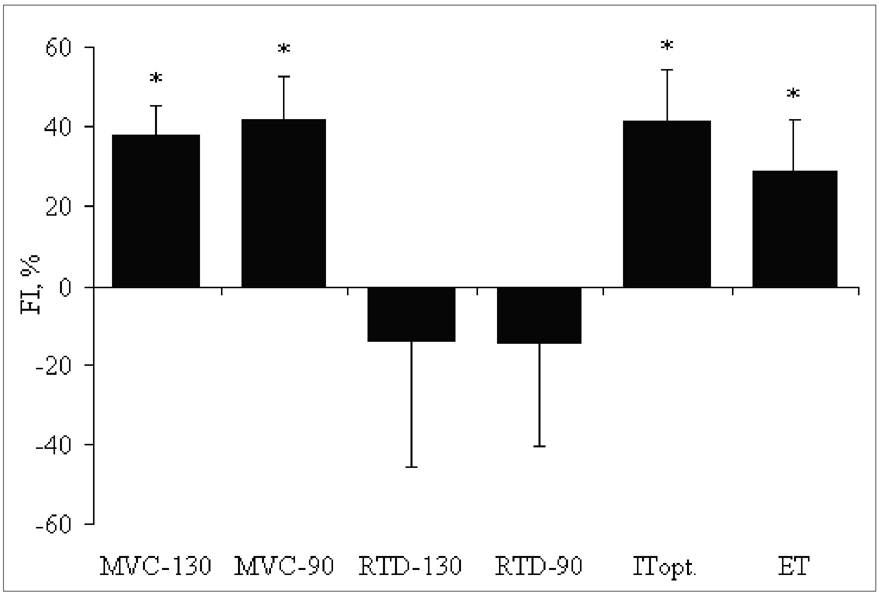
Note. * – $p < 0.05$, compared to pre-exercise values.

Figure 2. **The rate of torque development (RTD) at knee angle of 130 and 90 degrees before and after exercise**



Note. * – $p < 0.05$, compared between 130 and 90 degrees.

Figure 3. **The fatigue index (FI) after eccentric exercise (10 series of 12 repetitions)**



Note. MVC, RTD, ITopt., ET – maximal voluntary contraction torque, rate of torque development, optimal isokinetic torque and eccentric * – $p < 0.05$, compared to pre-exercise values.

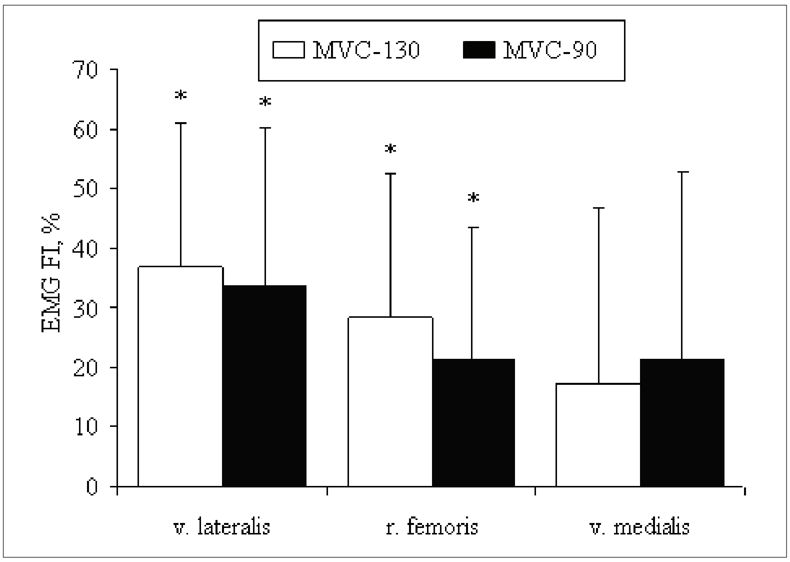


Figure 4. **The changes in EMG (rms) during maximal voluntary contraction at 130 and 90 knee angle degrees after eccentric exercise**

Note. * – $p < 0.05$, compared to pre-exercise values.

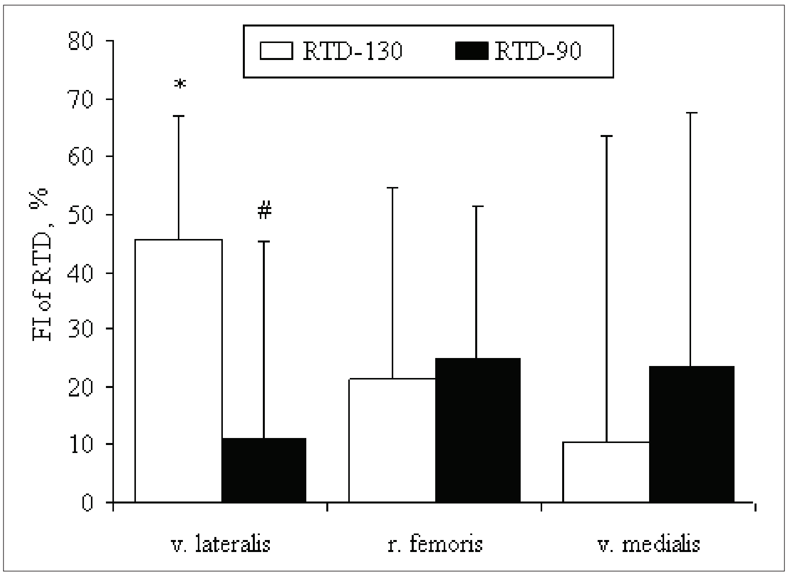


Figure 5. **The changes in EMG (rms) during 100 ms after onset of explosive isometric contraction at 130 and 90 knee angle degrees after eccentric exercise**

Note. * – $p < 0.05$, compared to pre-exercise values. # – $p < 0.05$, compared between 130 and 90 degrees.

Figures 2 and 3 show that all criteria of voluntary performace changed significantly ($p < 0.001$) after EE except for RTD, i. e. increased after EE. The changes in MVC and RTD did not depend on muscle length. However, the FI of MVC as well as ITopt was significantly greater than FI of ET. There was a significant decrease in EMG (rms) of *v. lateralis* and *r. femoris* after EE during MVC and it did not depend on muscle length (Figure 4). The results showed that EMG (rms) during 100 ms after onset of explosive isometric contraction decreased significantly after EE only in v. *lateralis* and only at 130 knee degrees (Figure 5).

DISCUSSION

The main findings of this study are: 1) length-dependent changes after eccentric exercise of quadriceps muscle torque are dependent on contraction type: more fatigue at shorter length manifests itself only during concentric isokinetic contraction; 2) RTD does not change after EE.

The main causes of changes in neuromuscular function after eccentric exercise. It has been recently concluded that there is no easy explanation for the strength loss following eccentric contractions since strength loss is a result of complex interaction of various mechanisms (Butterfield, Herzog, 2005; Prasartwuth et al., 2006). However, there is no doubt that in our case the main reasons for the decrease in voluntary induced muscle performance after EE are related to damage force-bearing structures (Clarkson, Hubal, 2002), excitation-contraction coupling system (Proske, Morgan, 2001; Skurvydas, et al., 2006) as well as changes in voluntary activation of muscle (Prasartwuth et al., 2006). After performing EE indirect symptoms of muscle damage manifested themselves within 24 h – 48 h after the load: the rise of muscle soreness, the increased CK activity, the decreased MVC, ET and ITopt (Figures 1 and 3), the shift ITopt to longer muscle length. The decreases in EMG (rms) during MVC after EE (Figure 4) shows that central fatigue might occur in our case.

Changes in MVC and RTD. It has been concluded that eccentric exercise-induced torque decrease is not contraction type dependent (Michaut et al., 2002) or ET decreased more than isometric one after ten sets of ten maximal concentric knee extensions (Michaut et al., 2003). V. Linnamo et al. (2000) established that ET decreased more than concentric torque after 100 maximal eccentric actions. In our case, however, ET decreased significantly less than ITopt (Figure 3). J. B. Thorlund et al. (2008) showed that MVC (about 10 per cent) and RTD decreased by 16–20 per cent following handball match play. However, MVC decreased in our case by about 30–40 percent while relative RTD did not change significantly (Figure 2). While maximum voluntary strength largely depends on the cross sectional area of the muscle, RTD is basically related to the discharge rate of the motor units recruited (Van Cutsem et al., 1998) and to the recruitment characteristics of motor units (Duchateau, Hainaut, 2003), that is it depends on neuromuscular drive of human skeletal muscle (Aagaard et al., 2002). There is no doubt that the efferent neuromuscular drive of human skeletal muscle is decreased after EE. This is in accord with our data that there is a significant change in absolute RTD after EE as well as in EMG (rms) during 100 ms of RTD at SL (Figure 5). Despite this, the changes in RTD after EE might be diminished by elevated muscle temperature of about 2.6 C degrees. It has been established by A. J. Sargeant (1987) that raising muscle temperature to a similar level increases RTD.

Length-dependent changes in isokinetic torque. To our knowledge it is the first study to have shown that there are length-dependent changes in the voluntary knee extension torque after EE: shorter muscle length, more fatigue index (Figure 6). Thought it is rather difficult to accurately determine the optimal angle due to flat torque at different angles but in our cases there is not any doubt that significantly more changes occur in torque at SL compared to LL (Figure 6). The rightward shift in the muscle length-tension relationship has been attributed to an increased series compliance of the muscle due to disrupted sarcomeres (Proske, Morgan, 2001; Gregory et al., 2007) and this shift has been proposed as a reliable indicator of muscle damage (Proske, Morgan, 2001; Philippou et al., 2004; Chen et al., 2007) as well as muscle fatigue (Butterfield, Herzog, 2006). This is in accord with our data, namely, that shift of optimal angle is significantly related to CK 48 after as well as to changes in ET after EE.

S. S. Yeung and E. W. Yeung (2008) also tested the optimal angle shift during isokinetic contraction (at 60deg/s). They found that after 10-minute stepping eccentric exercise there was a significant shift (about 4 degrees) in the peak torque angle to longer muscle lengths. Similar optimal angle shift (about 4 degrees) in isometric contraction after 30 eccentric actions was found by T. C. Chen et al. (2007). However, in our case the optimal angle shift to longer muscle length was much greater (about 12 degrees). This discrepancy might be explained by the fact that our eccentric exercise was much more intensive and therefore much greater muscle fatigue as well muscle damage was induced. It is rather strange that there are no length dependent changes in isometric MVC after EE, while this is observed during isokinetic contraction. It might be related to the fact that we tested MVC only at two angles, i. e. at 130 and 90 deg.

CONCLUSIONS AND PERSPECTIVES

We observed more changes in isokinetic torque at shorter muscle length after eccentric exercise induced muscle fatigue and damage. The changes in isometric MVC and RTD after eccentric exercise did not depend on the length of the muscle tested. Besides, relative RTD did not change after exercise.

Coaches, trainers and athletes need to be aware of the impact of exercise-induced muscle damage on the changes in length-related isokinetic torque in dynamic movements. The force decrease in any part of the range of motion during the exercises might affect overall performance. This study demonstrates that the effect of severe muscle-damaging exercises on isokinetic torque is the greatest at short muscle length, but this is not evident than performing isometric contractions. Therefore, these findings should be considered when applying this type of exercises and evaluating muscle function at a particular point in time.

REFERENCES

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology,* 93, 1318–1326.

Butterfield, T. A., Herzog, W. (2005). Quantification of muscle fiber strain during in-vivo repetitive stretch-shortening cycles. *Journal of Applied Physiology,* 99, 593–602.

Butterfield, T. A., Herzog, W. (2006). The magnitude of muscle strain does not influence serial sarcomere number adaptations following eccentric exercise. *Pflügers Archiv: European Journal of Physiology*, 451, 688–700.

Byrne, C., Twist, C., Eston, R. (2004). Neuromsucular function after exercise-induced muscle damage. Theoretical and applied implications. *The Journal of Sports Medicine,* 1, 49–69.

Chapman, D. W., Newton, M. J., Zainuddin, Z., Sacco, P., Nosaka, K. (2008). Work and peak torque during eccentric exercise do not predict changes in markers of muscle damage. *British Journal of Sports Medicine*, 42, 585–591.

Chen, T. C., Nosaka, K., Sacco, P. (2007). Intensity of eccentric exercise, shift of optimum angle, and the magnitude of repeated-bout effect. *Journal of Applied Physiology*, 102, 992–999.

Clarkson, P. M., Hubal, M. J. (2002). Exercise-induced muscle damage in humans. *American Journal of Physical Medicine & Rehabilitation*, 81, S 52–69.

Van Cutsem, M., Duchateau, J., Hainaut, K. (1998). Changes in single motor unit behaviour contribute to the increase in contraction speed after dynamic training in humans. *Journal of Physiology (London)*, 513, 295–305.

Duchateau, J., Hainaut, K. (2003). *Mechanisms of muscle and motor unit adaptation to explosive power training*. In P. V. Komi (Ed.), *Strength and Power in Sport*. Blackwell, Oxford. P. 315–330.

Gregory, J. E., Morgan, D. L., Allen, T. J., Proske, U. (2007). The shift in muscle's length-tension relation after exercise attributed to increased series compliance. *European Journal of Applied Physiology*, 99, 431–441.

Hubal, M. J., Rubinstein, S. R., Clarkson, P. M. (2008). Muscle function in men and women during maximal eccentric exercise. *Journal of Strength & Conditioning Research*, 22, 1332–1338.

Linnamo, V., Bottas, R., Komi, P. V. (2000). Force and EMG power spectrum during and after eccentric and concentric fatigue. *Journal of Electromyography & Kinesiology,* 10, 293–300.

McHugh, M. P., Tetro, D. T. (2003). Changes in relationship between joint angle and torque production associated with repeated bout effect. *Journal of Sports Sciences,* 21, 927–932.

Michaut, A., Pousson, M., Babault, N., Van Hoecke, J. (2002). Is eccentric exercise-induced torque decrease contraction type dependent? *Medicine & Science in Sports & Exercise,* 34, 1003–1008.

Michaut, A., Pousson, M., Millet, G., Belleville, J., Van Hoecke, J. (2003). Maximal voluntary eccentric, isometric and concentric torque recovery following a concentric isokinetic exercise. *International Journal of Sports Medicine,* 24, 51–56.

Philippou, A., Bogdanis, G. C., Nevill, A. M., Maridaki, M. (2004). Changes in the angle-force curve of human elbow flexors following eccentric and isometric exercise. *European Journal of Applied Physiology,* 93, 237–244.

Prasartwuth, O., Allen, T. J., Butler, J. E., Gandevia, S. C. (2006). Length-dependent changes in voluntary activation, maximum voluntary torque and twitch responses after eccentric damage in humans. *Journal of Physiology*, 15, 243–252.

Proske, U., Morgan, D. L. (2001). Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. *Journal of Physiology (London),* 537, 333–345.

Sargeant, A. J. (1987). Effect of muscle temperature on leg extension force and short-term power output in humans. *European Journal of Applied Physiology,* 56, 693–698.

Skurvydas, A., Kamandulis, S., Stanislovaitis, A. et al. (2008). Leg immersion in warm water, stretch-shortening exercise, and exercise-induced muscle damage. *Journal of Athletic Training*, 43, 592–599.

Skurvydas, A., Sipaviciene, S., Krutulyte, G. et al. (2006). Dynamics of indirect symptoms of skeletal muscle damage after stretch-shortening exercise. *Journal of Electromyography & Kinesiology, 1*6, 629–636.

Thorlund, J. B., Michalsik, L. B., Madsen, K., Aagaard, P. (2008). Acute fatigue-induced changes in muscle mechanical properties and neuromuscular activity in elite handball players following a handball match. *Scandinavian Journal of Medicine & Science in Sports*, 18, 462–472.

Warren., G. L., Lowe, D. A., Armstrong, R. B. (1999). Measurement tools used in the study of eccentric contraction-induced injury. *Sports Medicine,* 27, 43–59.

Yeung, S. S., Yeung, E. W. (2008) Shift of peak torque angle after eccentric exercise. *International Journal of Sports Medicine*, 29, 251–256.

VALINGŲ EKSCENTRINIŲ PRATIMŲ SUKELTO NUOVARGIO PRIKLAUSOMUMAS NUO RAUMENŲ ILGIO IR SUSITRAUKIMO TIPO

Albertas Skurvydas, Marius Brazaitis, Sigitas Kamandulis, Dalia Mickevičienė, Diana Karanauskienė
Lietuvos kūno kultūros akademija, Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Iškėlėme hipotezę, kad ekscentrinis krūvis (EK) sukels raumenų nuovargį ir pažeidą, kuri priklausys ne tik nuo testuojamo raumens ilgio, bet ir nuo susitraukimo tipo (ekscentrinis vs. koncentrinis vs. izometrinis).

Tikslas: patikrinti tyrimo hipotezę.

Metodai. Sveiki netreniruoti vyrai (vidurkis ± standartinis nuokrypis: amžius – 24,8 ± 3,7 m., n = 10) atliko 10 serijų po 12 kartojimų ekscentrinių keturgalvio šlaunies raumens susitraukimų esant fiksuotam 160°/s kampiniam greičiui. Prieš ir po EK matavome maksimaliąją valingą keturgalvio raumens izometrinio susitraukimo jėgą (MVJ), maksimalų jėgos didėjimo laipsnį (JDL) ir izokinetinę jėgą esant fiksuotam 30°/s kampiniam greičiui. Visi matavimai atlikti sulenkus kelio sąnarį skirtingu kampu. Be to, buvo matuojamas keturgalvio raumens elektrinis aktyvumas (EMG).

Rezultatai. Nustatytas reikšmingas JDL absoliučių reikšmių pokytis po EK (prieš EK: 3695 ± 803 N·m/s ir 2360 ± 695 N·m/s esant mažam ir dideliam raumens ištempimo ilgiui atitinkamai; po EK: 2574 ± 843 N·m/s ir 1517 ± 476 N·m/s esant mažam ir dideliam raumens ištempimo ilgiui atitinkamai). Aptiktas reikšmingas skirtumas tarp EMG reikšmių atliekant MVJ po EK, kai raumens ištempimo ilgis didelis ir mažas atitinkamai: šlaunies šoninio plačiojo (v. *lateralis*) raumens 0,32 ± 0,12 mV ir 0,24 ± 0,10 mV; tiesiojo šlaunies (r. *femoris*) raumens 0,25 ± 0,11 mV ir 0,17 ± 0,07 mV. Visi valingomis pastangomis paveikti rodikliai sumažėjo reikšmingai, išskyrus JDL (t. y. pastarasis padidėjo po EK).

Aptarimas ir išvados. Didesni izokinetinės jėgos pokyčiai po EK sukelto raumens nuovargio ir pažeidos buvo nustatyti esant mažesniam raumens ištempimo ilgiui. Nustatyti MVJ ir JDL pokyčiai po EK nepriklauso nuo testuoto raumens ištempimo ilgio. Be to, santykinis JDL po EK reikšmingai nepakito.

Raktažodžiai: ekscentriniai, koncentriniai ir izometriniai susitraukimai, raumens nuovargis ir pažeida, raumens ilgis, raumens jėga, jėgos momento išugdymo greitis.

Gauta 2011 m. liepos 23 d.
Received on July 23, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Albertas Skurvydas**
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 37 302620
E-mail a.skurvydas@lkka.lt

THE INFLUENCE OF NORDIC WALKING ON PHYSICAL FITNESS OF ELDERLY PEOPLE

Vaida Šokelienė, Vida Janina Česnaitienė
Lithuanian Academy of Physical Education, Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Nordic Walking is a form of physical activity which is rapidly gaining its popularity and is suitable for people of various ages and health conditions. We hypothesized that after 12 weeks of Nordic Walking exercises elderly people would experience certain changes, including increased flexibility of the lumbar spine area, increased strength endurance of the lower limbs, better aerobic endurance, decreased proportional fat mass.

Research aim was to determine and asses the influence of Nordic Walking on the physical capability of elderly people.

Research methods. The study included 41 subjects (11 men and 30 women): their average age was 65 ± 5 years. Physical activity of the subjects was evaluated according to their physical activity level and intensity evaluation questionnaire (RAPA). In order to determine physical fitness of the subjects we performed calf endurance test based on P. Mark and S. Tremblay's (1992) proposed methodology, lumbar spine flexibility was evaluated by the "sit-reach" test, spirometry, aerobic endurance test. The subjects performed Nordic Walking training sessions two times a week. The duration of the study was 12 weeks.

Research results. The people who engaged in the Nordic Walking practice sessions showed improved indicators of aerobic endurance, smaller body mass and lower ratio of waist/hip sizes. The flexibility of the lumbar spine area increased for the people who had been physical inactive.

Discussion and conclusions. Nordic Walking holds a positive impact on the physical capability of elderly people. Engagement in the Nordic Walking exercises has a more obvious effect on the physical capability of the people who are less physically active than of the people who are more physically active.

Keywords: physical activity, training, aging.

INTRODUCTION

The aging of human locomotor system is related to the constant decrease of muscle mass, strength, and power of contraction. Studies have shown that physical activity increases and helps maintain muscle strength and power, which provides the elderly's independence and unconstrained movement ability. People who have been inactive all their life and those who have started exercising at old age also felt positive results (Gaigalienė, 1999). Nordic Walking (NW) is one of the fastest-growing forms of physical activity in northern Europe, Scandinavia and Germany. This form of exercise is suitable for all ages. NW is safe, inexpensive, easy to get started sport with health benefits, intended for a pleasant leisure, but not for competitions. In

Finland, this type of sport engaged more than 850,000 inhabitants in 2008. In the world, it engaged 6 million people in 2005 and about 8.5 million in 2008 (INWA). There are many studies done showing the benefits of NW for people with various health problems (Church et al., 2002; Hansen et al., 2008). However, little is known how much NW may be useful for healthy elderly people. It was found that walking with sticks, unlike running, removes part of the load burden for leg joints and back, also correctly performed movements relax neck and shoulder muscles. Walking with sticks improves the capability of the cardiovascular system, and increases aerobic endurance. Studies have shown that this activity increases metabolism (Geyer, 2005). Therefore, the aim of this study was to evaluate the influence of NW on the physical fitness of elderly people.

RESEARCH METHODS

The study included 41 subjects, with an average age of 65 ± 5 years. Further characterization of the subjects is presented in Table.

The participants filled the form of physical activity levels and intensity evaluation suggested by the Health Promotion Research Center at the University of Washington (Topolski et al., 2006). The objective of the survey was to assess the physical activity of the subjects. The subjects' height was established with the gauge. Body mass measurements were evaluated by using body composition analyzer "TBF-300 (Germany), waist and hip size were assessed with the tape-measure.

In order to evaluate the flexibility of lumbar spine we used "Sit-reach" test of EUROFIT test batery, and calves endurance test conducted by P. Markon and S. Tremblay (1992) proposed methodology. The functional state of the respiratory system was assessed with a spirometer by measuring the vital capacity of the lungs. Aerobic endurance was evaluated using Roufier-Dixon index.

During the whole study the heart rate (HR) was recorded using pulse monitor *Polar S810* (Finland). The goal of the pulsometry was to measure the subjects' HR during all trials, according to which we individually selected safe and beneficial workloads for the subjects. The load was determined and controlled individually, according to the results of the HR after each workout.

The results were analyzed using the statistical package *SPSS 17.0 for Windows*. The impact of the NW was determined by the analysis of non-parametric criteria. To compare dependent variables we used Wilcoxon's test and for the independent-Kolmogorov-Smirnov Z test. All results were considered statistically significant when $p < 0.05$.

The detailed protocol of the study is provided in Figure 1.

During the first testing we evaluated all physical qualities of the three groups of subjects (lumbar spine flexibility, lower limb strength-endurance,

Table. **Characteristics of the subjects**

Groups of subjects	Men	Height, cm	Weight, kg	Women	Height, cm	Weight, kg
Group 1 PA subjects	3	1.69 (0.1)	64.53 (9.64)	8	1.62 (0.08)	56.39 (9.55)
Group 2 PINA subjects	4	1.82 (0.05)	92.15 (10.22)	10	1.62 (0.05)	72.34 (9.49)
Group 3 Control group	4	1.76 (0.07)	82.1 (7.37)	12	1.63 (0.06)	70.1 (13.67)

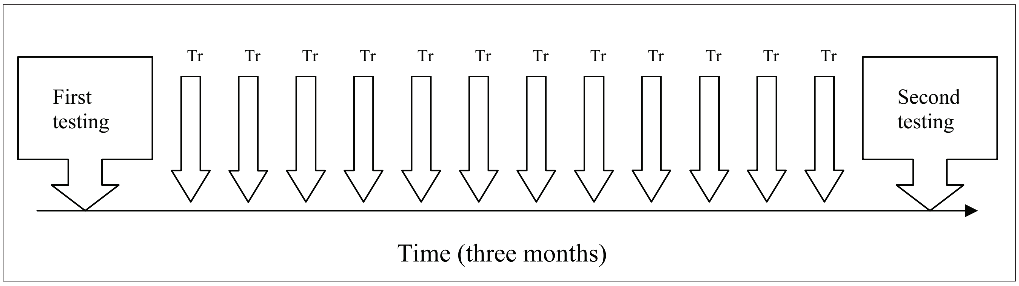


Figure 1. **The protocol of the research**

Note. Tr. – training.

vital capacity of lungs, aerobic endurance). We also assessed their stature, waist and hip size and body weight.

The first and the second groups of subjects participated in NW workouts. The workout plan was as follows: a 10-minute warm-up, 35-minute main part, and 5-minute stretching routine. During basic training the subjects walked on a smooth area. In accordance with the American College of Sports Medicine recommendations exercise intensity – 50–85% of maximum HR – was chosen.

The second testing was identical to the first one.

RESEARCH RESULTS

The changes of body weight mean values of the subjects are given in Figure 2. Average body weight of PA (PA) subjects decreased by 2 percent after training ($p < 0.05$), 5 percent in PINA (PINA) subjects ($p < 0.05$), and the same weight remained in the control group.

The changes of subjects' waist/hip ratio after NW workouts are presented in Figure 3. Waist/hip ratio mean values decreased in both groups of subjects (PA and PINA). PA subjects ratio decreased by 6% ($p < 0.05$), and in PINA subjects – 21% ($p < 0.05$).

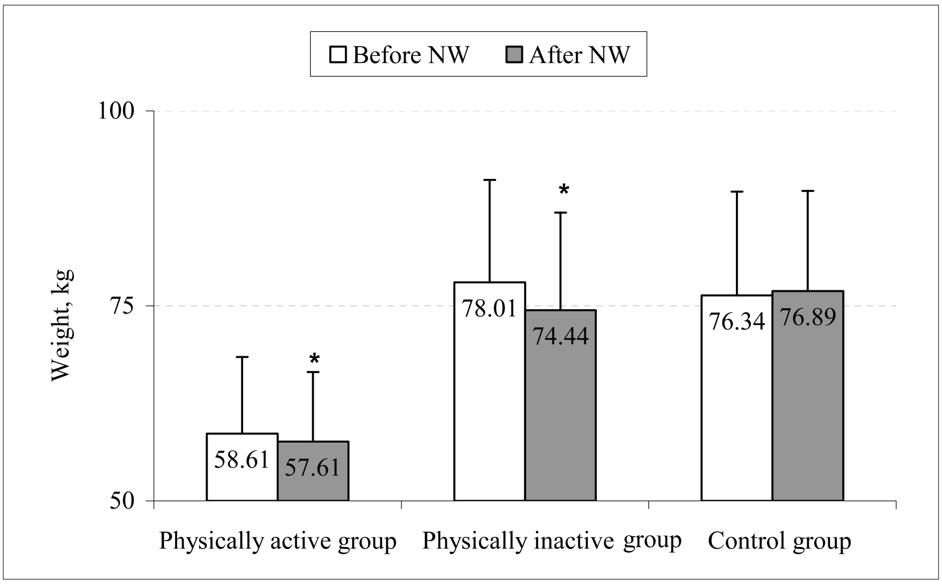


Figure 2. **Subjects' body weight (kg) before and after NW training**

Note.* – $p < 0.05$ compared to the body weight before the NW.

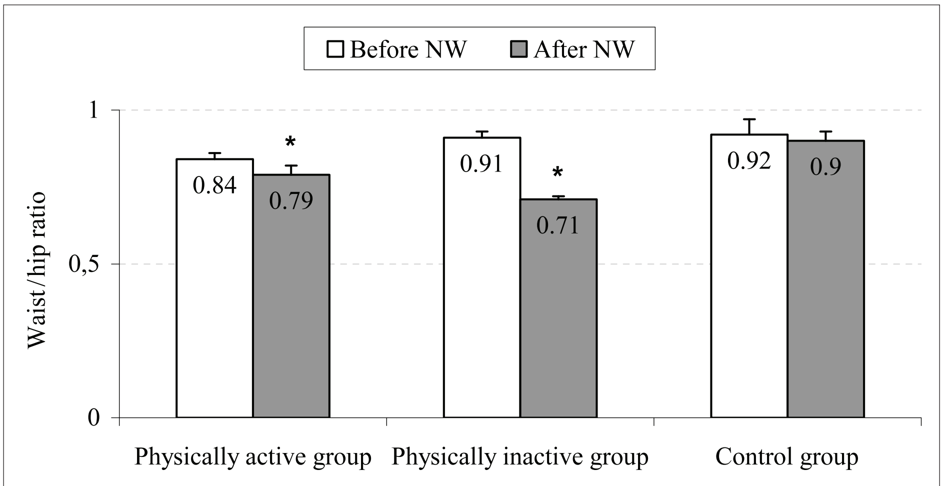


Figure 3. **Obtaining the waist/hip ratio before and after the Nordic Walking training**

Note. * – $p < 0.05$ compared to waist/hip ratio before the NW.

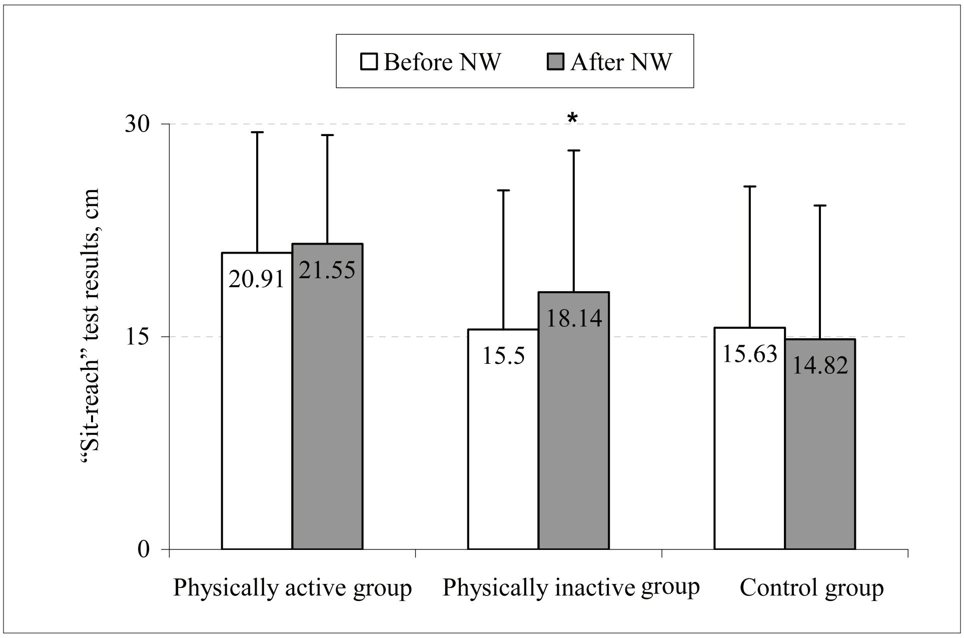
Analysis of the flexibility of the lumbar spine (Figure 4) based on “sit-reach” test showed that the results of PA subjects increased by 0.64 cm ($p > 0.05$), and the results of PINA subjects – 2.64 cm. ($p < 0.05$).

Figure 5 illustrates calf endurance test results. The parameters did not change significantly in all subjects after NW training.

The results of vital capacity of the lungs test before and after NW training are presented in Figure 6. The vital capacity of the lungs in PA subjects after NW training increased from 2.33 l to 2.65 ($p < 0.05$) and in PINA – from 2.36 l to 2.87 ($p < 0.05$). The vital capacity of the lungs in the control group did not change.

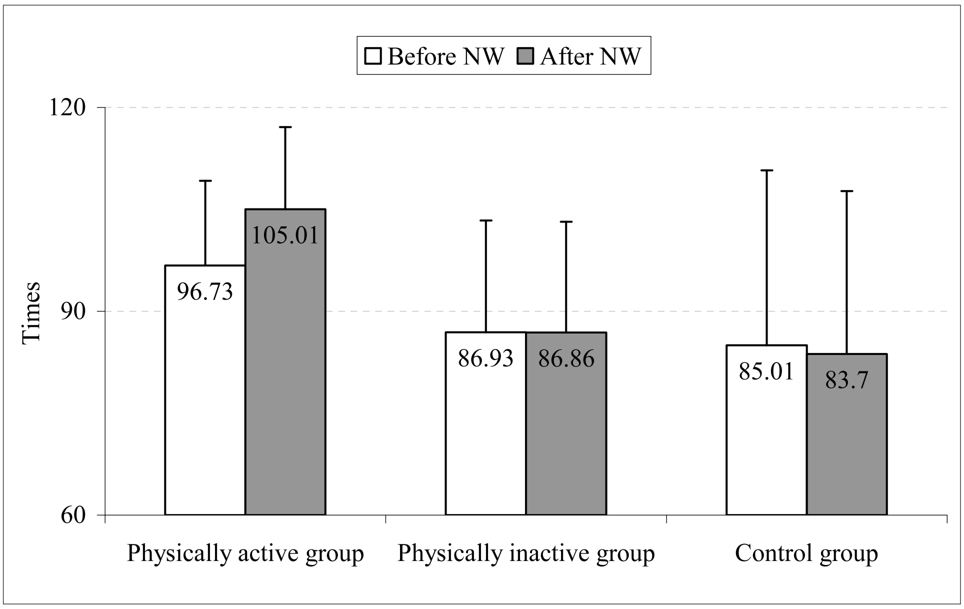
The results of subjects’ aerobic endurance test before and after NW training are provided in Figure 7. The results showed that aerobic endurance of the PA and PINA subjects after NW training improved significantly ($p < 0.05$). Roufier-Dixon index in PA subjects decreased from 7.85 to 5.65, in PINA subjects Roufier-Dixon index declined from 6.16 to 5.31, but Roufier-Dixon index increased from 5.22 to 5.48 in the control group.

Figure 4. **Subjects’ “Sit-reach” test results before and after NW training (cm)**



Note. * – $p < 0.05$ compared to lumbar spine flexibility before the NW.

Figure 5. **Subjects’ calf endurance test results distribution before and after the NW training (times of standing on tiptoe/min)**



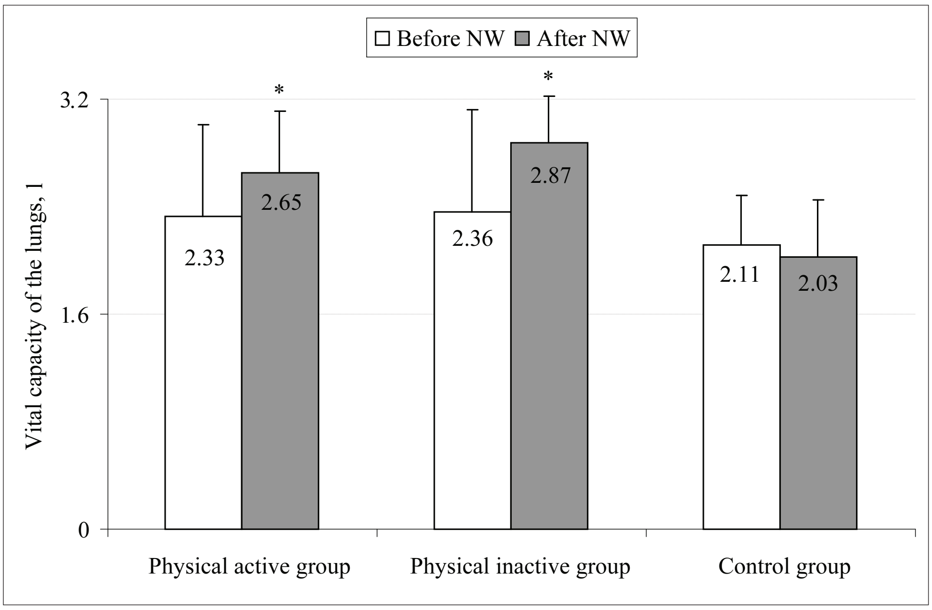


Figure 6. **Subjects' vital capacity of the lungs before and after NW training**

Note. * – $p < 0.05$ compared to the vital capacity of the lungs before NW.

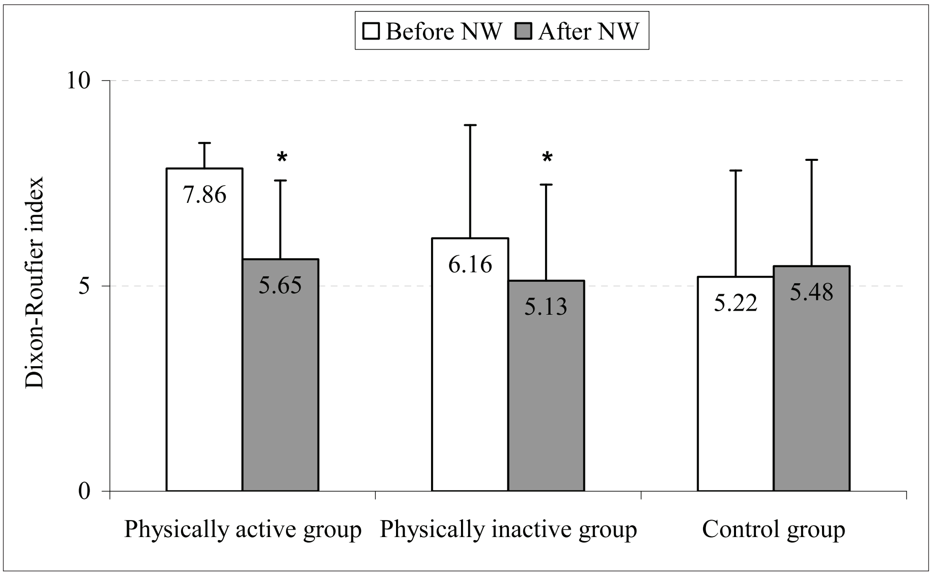


Figure 7. **Subjects' aerobic endurance test results before and after NW training (Dixon-Roufier index)**

Note. * – p < 0,05 compared to aerobic endurance before NW.

DISCUSSION

NW training significantly ($p < 0.05$) reduced the body weight of subjects. It decreased in PA subjects by 2%, and in PINA – 5%. These results confirm the findings of M. Rogers and colleagues (2010) study, which showed that NW training reduced body weight by 22%. However, T. S. Church and colleagues (2002) carried out an experimental the results of which argue the impact of NW training on body weight of subjects as it remained the same. However, many findings of foreign researchers confirm the positive effects of NW training for weight loss. They found that NW movements consume more calories than conventional walking (Church et al., 2002). W. Kohler's (2008) study showed that walking with sticks prevents age-induced decreased in bone density. Our study showed that waist/hip ratio of PA and PINA subjects after NW training significantly ($p < 0.05$) decreased.

J. Hartvigsen and colleagues (2010) conducted the first study that evaluated the effect of NW for subjects with back pain. They noted that NW is a useful workout for people suffering from back pain. Our study results showed positive effect of NW on lumbar spine flexibility. Statistically significant ($p < 0.05$) improvement of lumbar spine flexibility was found in PINA group – 2.64 cm. The lumbar spine flexibility of PA subjects improved as well, but the difference was not statistically significant ($p > 0.05$). Lumbar spine flexibility deteriorated in the control group 0.81 cm. ($p > 0.05$).

K. Kukkonen-Harjula and colleagues (2007) conducted a study which showed that triceps increased martedly after NW. They found the NW-induced increased upper body muscle endurance, but not strength. Our study did not reveal any effect of NW on leg endurance. The results of leg endurance test in all three groups of subjects after NW training did not show any statistically significant difference ($p > 0.05$).

T. S. Church and colleagues (2002) found that NW induced an increase in oxygen consumption. Study showed that the NW increased oxygen consumption by 23%. Our study results showed that PA subjects' vital capacity of lungs increased from 2.33 l to 2.65 l, and in PINA – from 2.36 l to 2.87 l.

Scientists suggest that aerobic endurance due to NW increase on average by about 20%. This percentage may be higher depending on the intensity of the workload. This is especially relevant for people who want to burn more calories and have certain health problems (Church et al., 2002). Studies show that walking increases aerobic endurance in healthy people as well as in patients suffering from chronic diseases. The benefits of walking for the metabolic and physiological processes have also been demonstrated (Quelle et al., 2002). The main discovery of the study is demonstrated a positive effect of NW on people with a history of cardiovascular diseases. The results showed that after three months of NW (three times a week, 70% intensity, 40–60 minutes a day), aerobic capacity of people with heart condition increased (Oka et al. 2000; Kocur et al., 2009). Our study showed that aerobic endurance were significantly ($p < 0.05$) improved because of NW training in both PA and PINA subjects. PA subjects' Roufier-Dixon index decreased from 7.85 to 5.65, and in PINA group this index decreased from 6.16 to 5.31.

CONCLUSIONS AND PERSPECTIVES

Nordic walking training had a positive effect on following investigated parameters of all subjects: aerobic endurance, body mass, waist/hip ratio, and in PINA subjects as well as the flexibility of lumbar spine.

REFERENCES

Breyer, M. K., Breyer-Kohansal, R., Funk, G. C. et al. (2010). Nordic Walking improves daily physical activities in COPD: A randomised controlled trial. *Respiratory Research*, 22, 11–112.

Church, T. S., Ernest, C. P., Morss, G. M. (2002). Field testing of physiological responses to Nordic Walking. *Research Quarterly for Exercise and Sport,* 73, 296–300.

Gaigalienė, B. (1999). *Pagyvenusių žmonių fizinis pajėgumas, aktyvus gyvenimo būdas ir sveikata.* Vilnius.

Geyer, K. (2005). Mit Stokeinsatz zum Ziel. *Physiopraxis*, 4, S 36–38.

Hansen, L., Henriksen, M., Larsen, P., Alkjaer, T. (2008). Nordic Walking does not reduce the loading of the knee joint. *Scandinavian Journal of Medicine and Science in Sports*, 18, 436–441.

Hartvigsen, J., Marso, L., Bendix, T., Manniche, C. (2010). Supervised and non-supervised Nordic walking in the treatment of chronic low back pain: A single blind randomized clinical trial. *BMC Musculoskeletal Disorders,* 11–30.

International Nordic Walking Federation (INWA). (2010). [2010 04 03]. Internet link: http://inwa-nordicwalking.com.

Kocur, P., Deskur-Smielecka, E., Wilk, M., Dylewicz, P. (2009). Effects of Nordic Walking training on exercise capacity and fitness in men participating in early, short-term inpatient cardiac rehabilitation after an acute coronary syndrome – a controlled trial. *Clinical Rehabilitation.*, 23 (11), 995–1004.

Kohler, W. (2008). Diagnostic algorithm for the differentiation of leukodystrophies in early MS. *Journal of Neurology*, 6, 123–126.

Kukkonen-Harjula, K., Hiilloskorpi, H., Manttari, M. et al. (2007). Self-guided brisk walking training with or without poles: A randomized-controlled trial in middle-aged women. *Scandinavian Journal of Medicine and Science in Sports,* 17, 316–323.

Markon, P., Tremblay, S. (1992). L'aide au maintien a domicile puor les perssones agees: Favoriser l'autonomie. *Universite du Quebec a Chicoutimi*, 555.

Oka, R. K., De Marco, T., Haskell, W. L. et al. (2000). Impact of a home-based walking and resistance training program on quality of life in patients with heart failure. *American Journal of Cardiology,* 85 (3), 365–369.

Quelle, K. J., Porcari, J. P., Franklin, B. A. et al. (2002). Is brisk walking an adequate aerobic training stimulus for cardiac patients? *Chest,* 122 (5), 1852–1856.

Rogers, M., Blumberg, N., Heal, J., Langa, K. (2010). Utilization of blood transfusion among older adults in the United States. *Medicine and Science in Sports and Exercise,* 32 (3), 18–24.

Topolski, T. D., LoGerfo, J., Patrick, D. L. et al. (2006). The Rapid Assessement of Physical Activity (RAPA) among older adults. *Prevention of Chronic Disease: Public Health Research, Practice and Policy,* 3 (4), A 118.

ŠIAURIETIŠKOJO ĖJIMO POVEIKIS VYRESNIOJO AMŽIAUS ŽMONIŲ FIZINIAM PAJĖGUMUI

Vaida Šokelienė, Vida Janina Česnaitienė
Lietuvos kūno kultūros akademija, Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hypotezė. Šiaurietiškasis ėjimas (ŠĖ) – vis populiarėjanti fizinio aktyvumo forma, tinkanti bet kokio amžiaus ar sveikatos būklės žmonėms. Atlikta nemažai tyrimų, įrodančių šiaurietiškojo ėjimo naudą žmonėms, turintiems įvairių sveikatos sutrikimų (Church et al., 2002, Hansen et al., 2008; Rodgers et al., 2010). Visgi mažai žinoma, kiek ŠĖ gali būti naudingas sveikiems vyresniojo amžiaus žmonėms. Manome, kad po 12 savaičių ŠĖ pratybų padidėja vyresniojo amžiaus žmonių juosmeninės stuburo dalies lankstumas, kojų jėgos ištvermė, pagerėja aerobinė ištvermė, sumažėja santykinė riebalų masė, keičiasi riebalų masės pasiskirstymas.

Tikslas: nustatyti ir įvertinti šiaurietiškojo ėjimo poveikį vyresniojo amžiaus žmonių fiziniam pajėgumui.

Metodai. Buvo tiriamas 41 asmuo (11 vyrų ir 30 moterų), kurių amžiaus vidurkis 65 ± 5 metai. Tiriamųjų fizinis aktyvumas nustatytas fizinio aktyvumo lygio ir intensyvumo vertinimo anketa (RAPA). Tiriamųjų fiziniam pajėgumui vertinti taikytas blauzdų ištvermės testas pagal P. Markon ir S. Tremblay (1992) metodiką, juosmeninės stuburo dalies lankstumas įvertintas testu „Sėstis–siekti“, taikyta spirometrija, aerobinės ištvermės testas. Šiaurietiškojo ėjimo pratybos vyko du kartus per savaitę. Tyrimas truko 12 savaičių.

Rezultatai. Po šiaurietiškojo ėjimo pratybų pagerėjo visų tiriamųjų aerobinės ištvermės rodikliai, sumažėjo kūno masė, juosmens ir klubų apimties santykis, padidėjo fiziškai neaktyvių tiriamųjų juosmeninės stuburo dalies lankstumas.

Aptarimas ir išvados. Šiaurietiškasis ėjimas teigiamai veikia vyresniojo amžiaus žmonių fizinį pajėgumą. Vyresniojo amžiaus žmonių, kurių fizinis aktyvumas nedidelis, fizinis pajėgumas po šiaurietiškojo ėjimo pratybų pagerėjo labiau nei fiziškai aktyvių.

Raktažodžiai: fizinis aktyvumas, treniravimas, senėjimas.

Gauta 2011 m. liepos 23 d.
Received on July 23, 2011

Priimta 2011 m. rugesėjo 9 d.
Accepted on September 9, 2011

Corresponding autor **Vida Janina Česnaitienė**
Lithuanian Academy of Pnysical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 37 302642
E-mail v.cesnaitiene@lkka.lt

CHANGES IN ATHLETIC FITNESS OF JUNIOR SPORTS DANCERS DURING A TEN-MONTH TRAINING CYCLE

Aistė Barbora Ušpurienė, Algirdas Čepulėnas
Lithuanian Academy of Physical Education, Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Research shows that the mastery level of dancers in sports dancing is closely related to their athletic fitness though there has not been enough research in the changes of indices of athletic fitness of junior sports dancers while training sports dancing. The present study aims at verifying the hypothesis that training in sports dancing should improve athletic fitness of sports dancers.

Research aim was to test the effect of training in sports dancing on the indices of athletic fitness of junior sports dancers.

Research methods. The subjects in the research were 14 junior sports dancers: 7 girls and 7 boys. The dancers were tested twice: in January 2010 and in November 2010. The training sessions were held three times a week. We established the following indices of athletic fitness: hand grip strength, the frequency of fine hand movements, the frequency of leg movement running on the spot for 10 s, speed of hand movements performing 25 cycles of movements, static balance, trunk flexibility, dynamic strength endurance of abdominal muscles, explosive strength and speed strength of legs, explosive strength endurance, simple and complex psychomotor reaction to light stimulus.

Research results. Dancing practice sessions had a positive effect on psychomotor abilities of boys and girls – simple psychomotor reaction for girls ($p < 0.05$) and simple and complex psychomotor reaction for boys ($p < 0.05$). The indices of athletic fitness of junior sports dancers did not change much in the research period.

Discussion and conclusions. Specialized dancing practice sessions did not have significant effect on the improvement of athletic fitness, however, a tendency of improvement in athletic fitness was observed. Athletic fitness is a significant component of junior sports dancers' sports fitness, and the improvement of athletic fitness indices requires inclusion of athletic training into the programs of training sports dancers, or regular practice sessions in sports dancing should be supplemented with physical exercises for the development of motor skills.

Keywords: sports dances, athletic training, motor skills, dancing practice sessions, training.

INTRODUCTION

Sports dances arouse much interest among scientists and experts as motor activity combining elements of sport and art expression (Haight, 1998; Карпенко, Сивицкий, 2009). The process of athlete training is oriented to sports results and is associated with the realization of physical abilities in the development of mastership, emotional satisfaction in dancing, the development of artistic abilities to express the idea of dance in body movements (Kavaliauskas, 2004; Рубштейн, 2005; Torrents et al., 2011). In sports dancing contests the pairs are evaluated according to the rhythm and plastic of movements, dancing technique, movement coherence, body posture and hand position, harmony of movements in a pair (Starosta, 2003; Карпенко, Сивицкий, 2009;

Климова, 2009). Synchronicity of movements, interaction between dancers, repeated sequences of movements, dancers' contacts dancing in a pair are of great importance (Torrents et al., 2011). Sports dancers perform non-standard dynamic movements at shifting intensities (Dornowski, Zabrocka, 2008). During a dance much time is spent performing the workload at the intensities exceeding the anaerobic threshold (Faina, Bria, 2000). The mastership of dancers much depends on their athletic fitness* (Miletić, 1999; Климова, 2009; Радионов, 2011).

Technical fitness of sports dancers is closely related to their motor skills: coordination, speed, flexibility, speed strength and endurance (Fostiak, 1996; Miletić, 1999; Pilewska, 2003; Климова, 2009). In standard and Latin American dancing the dancers need good general and special endurance (Репникова, 2004). The level of motor skills such as explosive strength, flexibility, speed, greatly influences the energy outlay of the human body in Latin American dances (Михайлов, 1999; Пискунова, 2004). The better the strength endurance of dancers, the lower the energy outlay in standard dancing (Репникова, 2004; Хемпшир, 2000). Professional literature highlights teaching and improving dancing technique (The Revised Technique of Latin-American Dancing ISTD, 1983), but little attention is paid to the problems of athletic training. Research sources (Kostić et al., 2003; Климова, 2009) maintain that training 5–7-year-old children, their program should include physical exercises for the development of their motor skills. The problem of athletic training of junior sports dancers has not received adequate attention yet (Терехова, 2007; Радионов, 2011). We suppose that changes in training and athletic fitness indices of junior sports dancers is a relevant research problem worth studying.

Research aim was to study the impact of training sports dancing on the indices of athletic fitness of junior dancers.

RESEARCH METHODS

The study was carried out in Jonava city sports dance club "Bonus" the head and the coach of which was Sergei Jefimenka. The subjects were 14 junior dancers – 7 boys and 7 girls. The mean age of the girls was 13.00 ± 1.00 years, and that of the boys was 13.33 ± 0.82 years. According to the age classifier in sports dancing (*Age Limitations*, 2009 – *Amžiaus apribojimai*, 2009) the subjects were attributed to junior group according to the mastery level in sports the subjects matched level E4, E6 and D classificatory classes (*Regulations of Classificatory Classes*, 2009 – *Kvalifikacinių klasių nuostatai*, 2009). The height of female dancers was 162.00 ± 8.14 cm, their body mass was 45.57 ± 6.97 kg, their body mass index –17.31 ± 1.87 kg/m^2. The boys' height was 164.17 ± 10.96 cm, body mass – 50.33 ± 11.84 kg, and their body mass index – 18.44 ± 1.87 kg/m^2. The dancers were tested two times. The first period of testing was January 2010, and the second – November 2010. Organized group training sessions with a coach were held three times a week. The dancers developed their technical, tactical and special fitness according to the coach's plan (Table 1). Besides group training sessions, on the other days the dancers trained individually independently or with a coach (individually paid classes).

Table 1. **Annual training plan for junior group dancers**

Periods	**Preparatory**		**Competition**		**Transition**	**Preparatory**		**Competition**			**Transition**	
Months	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII
Technical and special training,%	70	60	40	40	40	60	60	35	35	35	65	**Vacation**
Tactical training, %	30	40	60	60	60	40	40	65	65	65	35	
Competitions	-	+	+	+	-	-	+	+	+	+	-	
Number of hours for training a week	10	8	7	7	5	8	8	7	7	7	8	

* Athletic fitness is the level of training physical abilities and complex skills necessary for the chosen branch of sport and preconditioning good sports results (Dictionary of Sports Terms, 2002 – Sporto terminų žodynas, 2002).

(Skernevičius et al., 2004): running on the spot raising the knees high (when the thigh reaches the horizontal position) for 10 s; Tapping Test 3 × 10 s; hand movement speed test – the person had to perform 25 movements as fast as possible and to touch circles on a plane which were 60 cm apart from each other (Eurofit, 1993); Sit and Reach Test for 30 s (Johnson, Nelson, 1986); standing on the front foot of one leg until the person can keep balance, and the time is recorded; standing vertical jumps taking off with both feet without hand movement with a squat of 90°, and with a squat of 135° with hand movement.

Leg muscle fatigue and endurance were estimated when the dancers performed a serious of 20 jumps from a squat position at the angle of 90° (Skurvydas, Mamkus, 1990). Psychomotor reactions were measured applying diagnostic device KTD-8. We measured simple psychomotor reaction time, when the dancers knew exactly what stimulus they had to react to, and complex psychomotor reaction, when there were several stimuli, and the dancers had to react only to one of them. The subjects had to react to light stimuli.

During the group training sessions no physical exercises for athletic fitness and specific motor skills were performed. Two-week micro-cycle models were applied: the model of basic special training (Table 2) and direct training for competitions – pre-competition micro-cycle (Table 3). The **research methods** applied were as follows: literature review, one-alternative natural experiment, motor skill testing.

The research data were processed applying the methods of mathematical statistics (Microsoft Office Excel Programme). We calculated the arithmetic mean ($\bar{x}$), standard deviation (± SD), Student (*t*) test criterion, and index *p* for statistical significance. The level of significance was set at 95%, when $p < 0.05$.

The body composition indices of dancers were established according to the approved methods (Skernevičius et al., 2004). The hand grip strength was measured with a dynamometer which had to be clenched with maximal effort. Motor abilities (speed, flexibility, balance, strength endurance) were measured using recommended approved tests

Table 2. **The model of a weekly micro-cycle of practice sessions for basic special training**

Tuesday	Thursday	Friday
10 min warm-up	10 min warm-up	10 min warm-up
30 min improvement of the basics of technique of one standard dance (e. g. Slow Waltz) one by one and in pairs, without music (counting) and with music.	30 min improvement of the basics of technique of one Latin American dance (e. g. Rumba) one by one and in pairs, without music (counting) and with music.	15 min improvement of choreographies of standard dances in pairs.
20 min improvement of the variations of the same dance dancing in pairs.	20 min improvement of the variations of the same dance dancing in pairs.	10 min dancing of five dances for 1 min 30 s with minimal breaks of rest.
		15 min improvement of choreographies of Latin American dances in pairs.
		10 min dancing of five dances for 1 min 30 s with minimal breaks of rest.

Table 3. **The model of a weekly micro-cycle of pre-competition practice sessions**

Tuesday	Thursday	Friday
10 min warm-up	10 min warm-up	10 min warm-up
10 min improvement of Slow Waltz competitive programme in pairs	10 min improvement of Samba competitive programme in pairs	15 min improvement of choreographies of standard dances in pairs.
10 min improvement of Tango competitive programme in pairs	10 min improvement of Cha Cha Cha Dance competitive programme in pairs	10 min dancing of five dances for 1 min 30 s with minimal breaks of rest.
10 min improvement of Vienna Waltz competitive programme in pairs	10 min improvement of Rumba competitive programme in pairs	15 min improvement of choreographies of Latin American dances in pairs.
10 min improvement of Quickstep competitive programme in pairs	10 min improvement of Jive Dance competitive programme in pairs	10 min dancing of five dances for 1 min 30 s with minimal breaks of rest.

RESEARCH RESULTS

Research findings given in Tables 4 and 5 allow estimating the achieved levels of motor skills (speed, flexibility, balance, strength endurance) for speed dancers – boys and girls. The frequency of steps for girls was 40.57 ± 4.86 steps during 10 s in the first study, and that for boys was 47.64 ± 1.51 steps, and in the second study they were at the same level ($p > 0.05$). The speed of hand movement can be evaluated can be estimated according to the time needed for 25 movement cycles for the

Table 4. **Changes in the indices of athletic fitness for junior girls in sports dancing**

Research stages	Indices	Hand grip strength, kg		Number of steps while running in place during 10 s, times	Hand movement speed–time needed for 25-movement cycles, s		Number of fine movements during 30 s in tapping test, times	Sit and lie down test during 30 s, times	Sit and reach test, cm	Vertical jump in place taking off with both feet, cm		
		Left hand	Right hand		Left hand	Right hand				With a squat at the angle of 90°	With a squat at the angle of 130°	With hand movement
I	$\bar{x}$	17.00	18.43	40.57	13.44	12.61	146.43	24.43	36.57	22.49	16.36	27.07
	± SD	4.20	4.24	4.86	1.15	1.30	5.38	4.12	5.16	3.42	3.99	4.43
	Min	12.00	12.00	32.00	12.10	11.10	141.00	21.00	30.00	19.00	14.00	21.00
	Max	23.00	24.00	48.00	15.30	14.80	156.00	32.00	44.00	27.00	22.00	32.00
II	$\bar{x}$	18.43	19.14	41.14	12.70	11.91	142.29	24.43	36.86	23.68	17.05	27.29
	± SD	4.04	3.76	5.02	1.06	1.37	9.39	4.68	4.88	3.72	3.75	4.43
	Min	13.00	15.00	32.00	11.4	10.10	12.90	21.00	31.00	20.00	15.00	21.00
	Max	25.00	24.00	48.00	14.3	14.20	156.00	32.00	44.00	29.00	23.00	32.00
	p	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05	< 0.05	> 0.05	> 0.05	< 0.05	< 0.05	> 0.05

Table 5. **Changes in the indices of athletic fitness for junior boys in sports dancing**

Research stages	Indices	Hand grip strength, kg		Number of steps while running in place during 10 s, times	Hand movement speed–time needed for 25-movement cycles, s		Number of fine movements during 30 s in tapping test, times	Sit and lie down test during 30 s, times	Sit and reach test, cm	Vertical jump in place taking off with both feet, cm		
		Left hand	Right hand		Left hand	Right hand				With a squat at the angle of 90°	With a squat at the angle of 130°	With hand movement
I	$\bar{x}$	24.00	24.50	47.67	13.13	12.47	141.83	29.50	30.50	22.45	14.48	30.14
	± SD	3.03	2.59	1.51	2.85	0.87	10.21	3.62	6.57	6.13	2.11	8.25
	Min	20.00	21.00	46.00	11.30	11.90	129.00	24.00	20.00	14.00	11.00	21.00
	Max	28.00	28.00	50.00	18.80	14.20	156.00	33.00	36.00	32.00	17.00	43.00
II	$\bar{x}$	25.00	25.00	47.08	12.72	12.12	146.67	30.33	30.83	22.75	15.68	28.33
	± SD	2.97	2.37	1.24	2.70	1.00	5.85	3.44	5.98	6.35	2.45	9.33
	Min	21.00	22.00	45.00	11.00	11.10	140.00	25.00	21.00	15.00	12.00	17.00
	Max	29.00	28.00	48.00	18.10	14.00	156.00	33.00	36.00	32.00	19.00	43.00
	p	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05	< 0.05	> 0.05	> 0.05	> 0.05	> 0.05	< 0.05

right and the left hands. In the first study the girls performed 25–movement cycles with the right hand in 12.61 ± 1.30 s, with the left hand – in 13.44 ± 1.15 s, for boys those indices were relatively 12.47 ± 0.87 and 13.13 ± 2.85 s. In the second study the indices of hand movement speed for girls and boys were slightly higher, but the changes were not statistically significant ($p > 0.05$). The number of fine movements of boys (Tapping Test) during 30 s increased from 141.83 ± 10.21 to 146.67 ± 5.85 times ($p < 0.05$), but for girls it decreased ($p < 0.05$). Both girls and boys achieved the greatest number of fine movements during the first 10 s, and later the frequency of movements gradually decreased (Figure 1, 2).

Flexibility of girls was better than that of boys (Table 4, 5), and in the second study the index of flexibility for girls was 36.86 ± 4.88 cm, and for boys – 30.83 ± 5.98 ($p < 0.05$). Both girls and boys achieved higher indices of static balance standing on one foot in the third trial in the first and the second studies (Figure 3, 4). The hand-grip strength of the left hand of girls and boys increased during the second study, but the changes were insignificant ($p > 0.05$).

The indices of the Sit up Lie down Test during 30 s (Table 4, 5) did not change during the whole research ($p > 0.05$). Dynamic strength endurance of the boys' abdominal muscles was better than that of the girls ($p < 0.05$). The indices of the vertical jumps show the explosive strength of legs (jump from a squat position at the angle of 90°) and speed strength (jump from a squat position at the angle of 130°). The explosive strength of leg muscles of both boys and girls tended to improve in the course of the study, but the changes were low ($p > 0.05$). The indices of 20-jump series show that strength endurance of leg muscles in girls and boys slightly improved (Figure 5, 6). The average height of jump in a series during the second study was 19.57 ± 0.50 cm for girls and 22.57 ± 0.84 cm for boys. Simple psychomotor reaction for boys and girls (Table 6) performing the task with the right and the left hands improved ($p < 0.05$). The

Figure 1. **Changes in the frequency of hand movements for girls in 30 s**

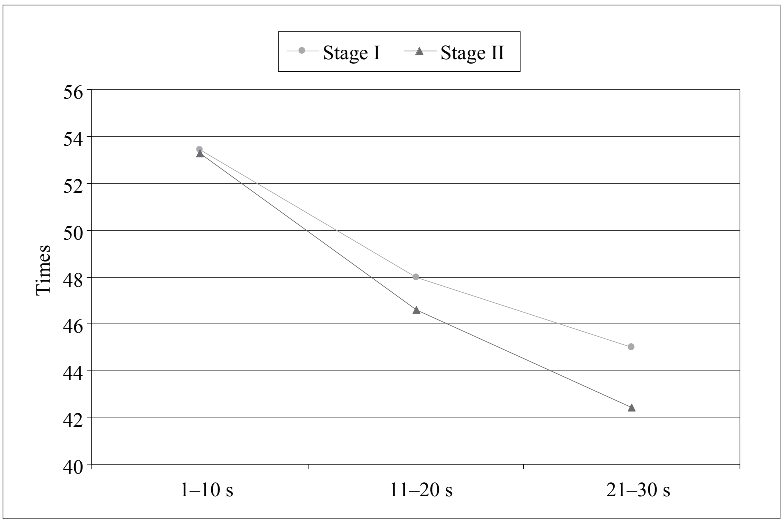
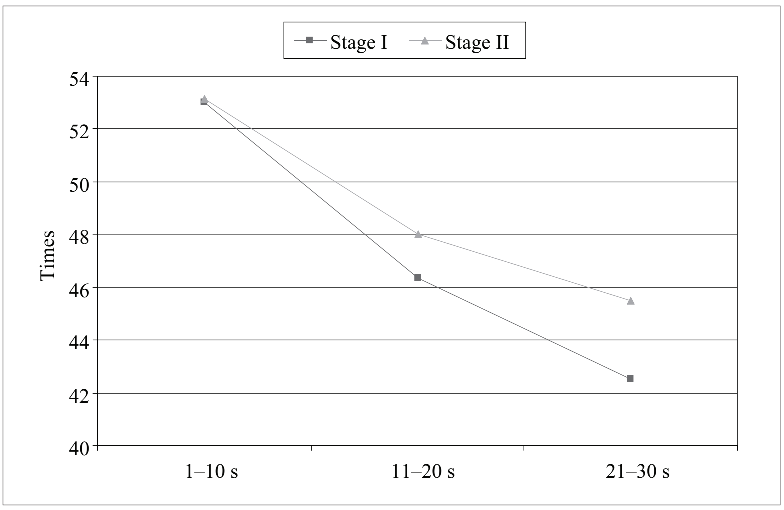


Figure 2. **Changes in the frequency of hand movements for boys in 30 s**



indices of complex psychomotor reaction for boys in the second study were higher compared to the first study ($p < 0.05$). The girls' indices of complex psychomotor reaction were higher when the task was performed with the right hand ($p < 0.05$), but for boys the complex psychomotor reaction reactions did not differ when the task was performed with the right or the left hands.

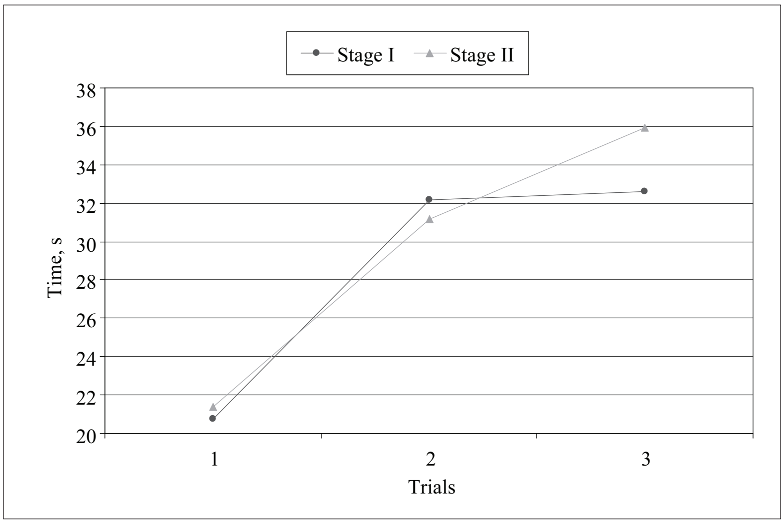


Figure 3. **Indices of standing on the front foot of one leg for girls**

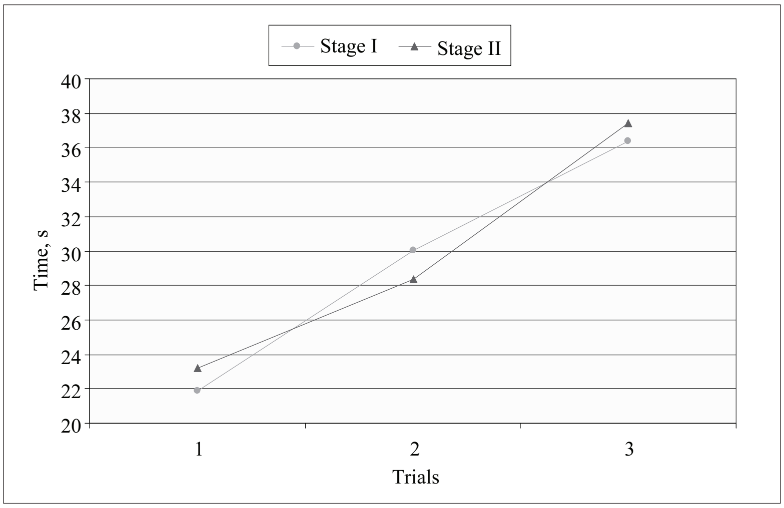


Figure 4. **Indices of standing on the front foot of one leg for boys**

Table 6. **Changes in the indices of psychomotor reactions for boys and girls in junior group of dancers**

Research stages	Indices	Girls				Boys			
		Simple reaction time, ms		Complex reaction time, ms		Simple reaction time, ms		Complex reaction time, ms	
		Left hand	Right hand	Left hand	Right hand	Left hand	Right hand	Left hand	Right hand
I	$\bar{x}$	305.33	303.05	325.52	283.71	226.44	243.56	287.00	291.11
	± SD	42.27	30.17	27.01	37.87	35.75	16.25	45.72	31.79
	Min	244.00	268.00	280.00	255.00	182.00	225.00	234.00	258.00
	Max	360.00	341.00	342.00	359.00	261.00	261.00	291.00	328.00
II	$\bar{x}$	267.57	255.57	309.86	259.57	194.33	194.67	243.33	243.67
	± SD	53.89	48.40	30.29	28.45	27.63	30.52	35.85	9.31
	Min	218.00	191.00	268.00	229.00	161.00	159.00	199.00	232.00
	Max	337.00	298.00	340.00	311.00	222.00	227.00	277.00	252.00
	p	< 0.05	< 0.05	> 0.05	> 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Figure 5. **Changes in the height of jumps for girls performing a series of 20 jumps**

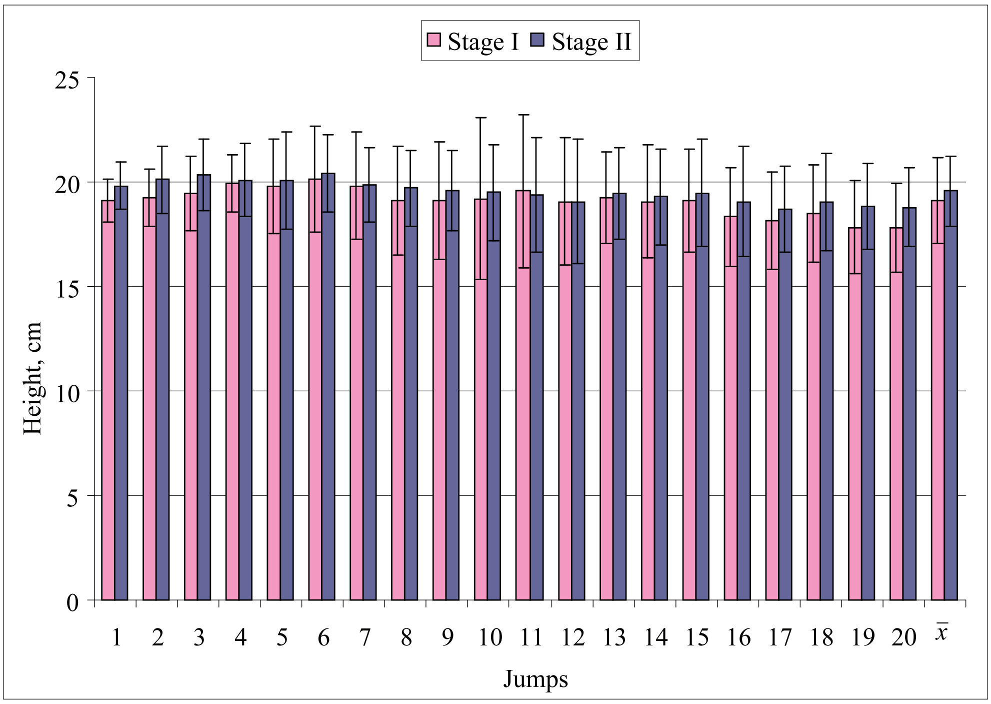
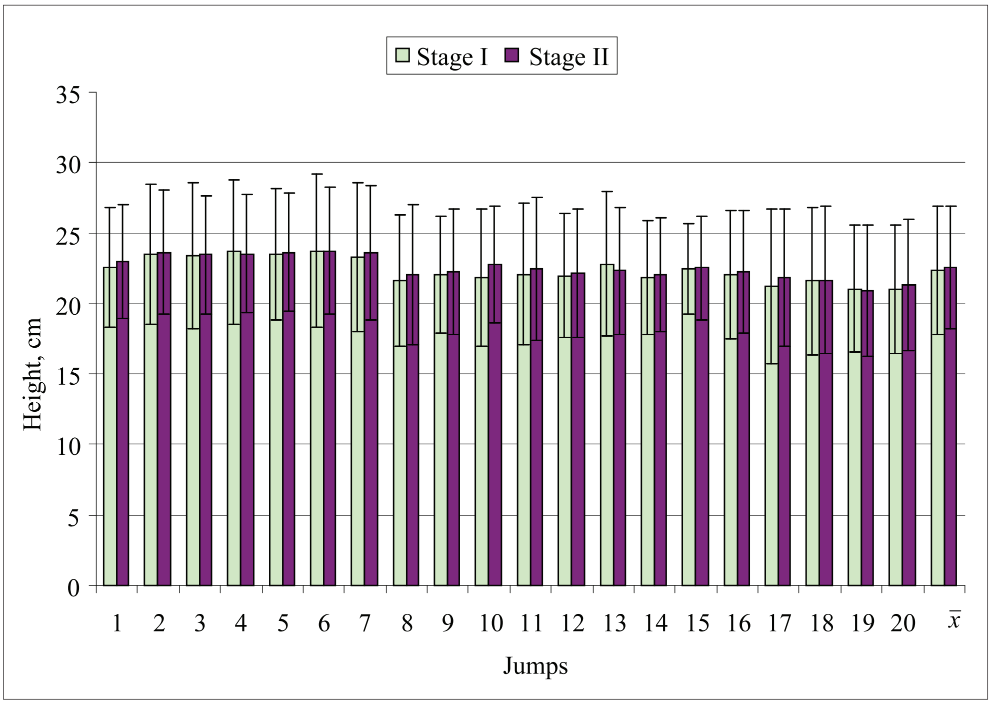


Figure 6. **Changes in the height of jumps for boys performing a series of 20 jumps**



DISCUSSION

Summing up the process of training junior dancers in sports dancing, we can distinguish the following essential things:

- The greatest attention was paid to teaching elements of dancing techniques and combining them into the whole.
- Dancing technique was taught and improved performing dancing exercises individually without music and with music and then harmonizing with the partner and the partner's movements.
- In the pre-competition cycles the contest program or parts of it are performed modeling the conditions of a competition.
- Practice sessions of athletic training were not conducted. No physical exercises for the development of motor skills were performed during the dancing practice sessions.

Training young sports dancers much attention should be paid to athletic training (Kostić et al., 2003; Карпенко, Сивицкий, 2009; Климова, 2009; Радионов, 2011). In practice, dancers develop their athletic fitness independently, and not in the practice sessions with a coach. Research shows that athletic fitness of young dancers improves more rapidly when dancing practice sessions include athletic training or physical exercises for the development of motor skills (Радионов, 2011).

The speed of leg movements of boys and girls performing the test "Frequency of steps running on the spot during 10 s" matched the level of persons engaged in sports (Skernevičius et al., 2004). Both boys and girls produced higher indices of step frequency running for 10 s then adult D Class male and female dancers (Ušpurienė, Čepulėnas, 2011). The speed of hand movements of boys and girls matched the average level of 13–14-year-old schoolchildren (*Eurofit*, 1993). Changes in the frequency of fine movements of the hand showed that the nervous system of female and male junior dancers is not capable of maintaining constant maximal frequency of fine movements. We believe that those indices are very important for dancers as they show the dancers' speed of spread of nervous impulses and the ability of muscles to adopt impulses (Dadelienė, 2008).

The results of the test "Sit up Lie down during 30 s" of junior dancers matched the girls' average level and the boys' high level of physical fitness of children of the same age according to the scale of physical fitness in Eurofit (1993). Flexibility indicators for both boys and girls according to the scale of B. L. Johnson, J. K. Nelson (1986) were rather high. The girls' duration indicator standing on the front of one leg (static balance) in the first study was 32.63 ± 14.69 s, and in the second one – 35.96 ± 11.28 s. The balance indices of female adult D class dancers according to this test were from 44.43 ± 9.57 s to 56.43 ± 18.85 s (Ušpurienė, Čepulėnas, 2011). The boys' duration indicator standing on the front of one leg during the second study was longer and it reached 37.40 ± 19.36 s the relative indices of male adult D class dancers were from 41.43 ± 5.19 s to 48.86 ± 18.25 s (Ušpurienė, Čepulėnas, 2011).

In sports dancing, body balance during the whole dance is of great importance (Czabański, 2000). The ability to maintain static balance helps to keep balance in the required positions, and keeping dynamic balance helps to perform various movements and actions under the influence of external powers (Dornowski, Zabrocka, 2008). The results of the jump with hand movements show the power of single leg muscle contraction (Skernevičius et al., 2004). The indices of girls' jump with hand movements corresponded to the average level of junior dancers according to A. Mero et al. (1992) scale. For boys the level was high. Dancing practice sessions had a remarkable positive effect on the psychomotor domain of boys and girls, the indices of simple and complex psychomotor reactions improved ($p < 0.05$). It is worth noting that that the indices of simple and complex psychomotor reactions of junior boys and girls were lower than those of adult D class male and female dancers (Ušpurienė, Čepulėnas, 2011). Psychomotor abilities are very important components of athletic fitness in sports dancing (Czabański, 2000).

Summing up the research findings we suggest that specialized dancing practice sessions did not have greater effect on the improvement of dancers' athletic fitness, but we could observe a tendency of improvement of some athletic fitness elements. The junior dancers' indices of speed, flexibility, strength endurance and explosive strength were adequate to those of boys and girls of the same age group and complied with the average or high level standards.

CONCLUSIONS AND PERSPECTIVES

- The indices of athletic fitness of junior sports dancers did not change much in the research period. Loads of technical and special training did not affect the changes in dancers' motor skills.
- Athletic fitness is a significant component of junior sports dancers' sports fitness, and the improvement of athletic fitness indices requires inclusion of athletic training into the programs of training sports dancers, or regular practice sessions in sports dancing should be supplemented with physical exercises for the development of motor skills.

Acknowledgments. We would like to thank the coach Sergej Jefimenka for allowing investigating dancers in his group.

REFERENCES

Amžiaus apribojimai. (2009). [2010 1 20]. Internet link: http://www.dancesport.lt/nariams/.

Czabański, B. (2000). *Kształcenie psychomotoryczne.* Wrocław: AWF.

Dadelienė, R. (2008). *Kineziologija: monografija*. Vilnius: LSIC.

Dornowski, M., Zabrocka, A. (2008). *Static and Dynamic Body Balance Maintenance Ability in Young Dance Sport Atletes on the Beginning Stage of Training. World Congress of Performance Anglysis of Sport VIII.* Book of Proceedings. Magdeburg. (pp. 577–581).

Eurofitas. (1993). Fizinio pajėgumo testai ir metodika. Parengė V. Volbekienė. Vilnius: LSIC.

Faina, M., Bria, S. (2000). *Is dancesport a leisure / wellness activity and / or sport?* [21 09 2009]. Internet link: http://__www.idsf.net/documents/dancesport_a_sport.pdf.

Fostiak, D. (1996). *Koordynacja ruchowa u zawodników gimnastyki artystycznej, łyżwiarstwa figurowego i sportowego tańca towarzyskiego.* Wydawnictwo Uczelniane AWF w Gdansku.

Haight, H. (1998). Morphologic, physiologic and functional interactions in elite female ballet dancers. *Medical Problems of Performing Artists,* 13 (1), 4–13.

Johnson, B. L., Nelson, J. K. (1986). *Practical Measurements for Evaluation in Physical Education.* United States of America.

Kavaliauskas, G. (2004). *Šokio ABC.* Kaunas: LKKA.

Kostić, R., Miletić, D., Jocić, D., Uzunović, S. (2003). *The Influence of Dance Structures on the Motor Abilities of Preschool Children.* [2009 12 02]. Internet link: http://www.facta.junis.ni.ac.rs/pe/pe2002/pe2002-08.pdf.

Kvalifikacinių klasių nuostatai. (2009). [2010 12 03]. Internet link: http://www.dancesport.lt/nariams/.

Mero, A., Komi, P., Gregor, R. (1992). Biomechanics of sprint running: A review. *Sports Medicine*, 13, 376–392.

Miletić, D. (1999). Factors of successfulness with folk dances. In P. Parisi, F. Pigozzi, G. Prinzi (Eds.), *Fourth ECSS Proceedings Book*. Rome, Italy. P. 374.

Pilewska, W. (2003). *Sprawność fizyczna i cechy budowy somatycznej jako podstawa modelowych charakterystyk zawodniczek i zawodników w tańcu sportowym: praca doktorska.* AWFiS Gdańsk.

Skernevičius, J., Raslanas, A., Dadelienė, R. (2004). *Sporto mokslo tyrimų metodologija.* Vilnius: LSIC.

Skurvydas, A., Mamkus, G. *(Parengė).* (1990). *Sportininkų perspektyvumo įvertinimas, remiantis raumenų kompozicija: metodinės rekomendacijos*. Vilnius.

Sporto terminų žodynas. (2002). Parengė S. Stonkus. *2-as pat. ir pap. leidimas*. Kaunas: LKKA. P. 411.

Starosta, W. (2003). *Motoryczne zdolności koordynacyjne (znaczenie, struktura, uwarunkowania, kształtowanie)*. Warszawa: Instytut Sportu w Warszawie.

The Revised Technique of Latin-American Dancing ISTD. (1983). London: Lithoflow LTD.

Torrents, C., Castañer, M., Anguera, M. T. (2011). Dancing with complexity: Observation of emergent patterns in dance improvisation. *Ugdymas. Kūno kultūra. Sportas,* 1 (80), 76–82.

Ušpurienė, A. B., Čepulėnas, A. (2011). D klasės sportinių šokių šokėjų fizinio parengtumo rodikliai ir jų kaita per metinius rengimo ciklus. *Sporto mokslas,* 1 (63), 50–56.

Карпенко, Л. А., Сивицкий, В. А. (2009). Базовая подготовка в спортивных танцах на паркете. *Учёные записки*, 5 (51), 36–40.

Климова, М. В. (2009). *Содержание и методика физической подготовки юных танцоров (на примере эстрадно сценического танца): автореферат диссертации.* Белгород: Белгородский государственный университет.

Михайлов, И. А. (1999). Использование упражнений в технической подготовке спортсменов-танцоров. В. И. А. Михайлов, Н. А. Коваленко, *Спортивные танцы: бюллетень. Проблемы управления, информационного обеспечения и преподования в спортивных танцах.* РГАРК. паб. Спорт. танцов. Москва. С. 26–43.

Пискунова, Л. В. (2004). Упражнения на растяжку в спортивно-технической подготовке спортсменов-танцоров. В. Л. В. Пискунова, *Материалы 8-й Всерос. науч.-метод. конф. по проблемам развития танцевальных видов спорта.* Москва, 2–6 февр. (сс. 39–41.)

Радионов, М. В. (2011). Физическая подготовленность юных спортсменов-танцоров как средство повышения спортивного результата. *Теория и практика физической культуры,* 4, 58–61.

Репникова, Е. А. (2004). Применение статодинамических упражнений в системе оздоровительной физической культуры. В. Е. А. Репникова, *Спортивные танцы: бюлетень. Материалы VIII Всерос. науч.-метод. конф. по проблемам развития танцевальных видов спорта.* Москва, 2–6 февр. ч. II. (сс. 17–18).

Рубштейн, Н. (2005). *V национальный конгресс тренеров и судей ФТСР. Лекция по психологии* [20 01 2008]. Internet link: http://www.dancesport.ru/articles/articles_40/art_68.phtml.

Терехова, М. А. (2007). Экспериментальное обоснование методики специальной физической подготовки юных танцоров на этапе начальной специализации. *Физическая культура, образование, тренировки*, 3, 42–43.

Хемпшир, Г. С. (2000). Венский вальс. Как воспитать чемпиона. В. Г. С. Хемпшир, *Современый бальный танец*. Москва: Артис. С. 288.

JAUNIŲ GRUPĖS SPORTINIŲ ŠOKIŲ ŠOKĖJŲ ATLETINIO PARENGTUMO KAITA PER DEŠIMTIES MĖNESIŲ TRENIRUOTĖS CIKLĄ

Aistė Barbora Ušpurienė, Algirdas Čepulėnas
Lietuvos kūno kultūros akademija, Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Sportinių šokių šokėjų meistriškumas yra glaudžiai susijęs su jų atletiniu parengtumu, tačiau nėra plačiai ištyrinėti jaunių grupės šokėjų atletinio parengtumo rodiklių kaitos ypatumai šokant sportinius šokius. Tyrimu siekiama patikrinti hipotezę, kad treniruojantis turėtų gerėti jaunių grupės sportinių šokių šokėjų atletinis parengtumas.

Tikslas: ištirti sportinių šokių pratybų poveikį jaunių grupės sportinių šokių šokėjų atletinio parengtumo rodiklių kaitai.

Metodai. Buvo tiriama 14 jaunių grupės šokėjų: 7 mergaitės ir 7 berniukai. Šokėjai testuoti du kartus: 2010 m. sausio ir lapkričio mėnesiais. Šokių pratybos vyko tris kartus per savaitę. Nustatyti šie atletinio parengtumo rodikliai: rankų plaštakų jėga; smulkių rankos judesių dažnis; kojų judesių dažnis bėgant vietoje 10 s; rankos judesių greitumas atliekant 25 judesių ciklus; statinė pusiausvyra; liemens lankstumas; pilvo raumenų dinaminė jėgos ištvermė; kojų staigioji jėga ir greitumo jėga; staigiosios jėgos ištvermė; paprastoji ir sudėtingoji psichomotorinė reakcija į šviesos dirgiklį.

Rezultatai. Šokių pratybos turėjo didelį teigiamą poveikį šokėjų mergaičių ir berniukų psichomotorikai – pagerėjo mergaičių paprastoji psichomotorinė reakcija ($p < 0,05$), berniukų – paprastoji ir sudėtingoji ($p < 0,05$). Jaunių grupės sportinių šokių šokėjų atletinio parengtumo rodikliai tiriamuoju laikotarpiu mažai kito.

Aptarimas ir išvados. Specializuotos sportinių šokių pratybos didesnio poveikio šokėjų atletinio parengtumo gerėjimui nepadarė, tačiau pastebėta atletinio parengtumo gerėjimo tendencija. Norint paspartinti šokėjų atletinio parengtumo gerėjimą, reikėtų į jaunių grupės sportinių šokių šokėjų treniravimo programas įtraukti fizinius pratimus atletiniam parengtumui tobulinti.

Raktažodžiai: sportiniai šokiai, atletinis rengimas, judamieji gebėjimai, šokių pratybos, atletinis parengtumas, treniravimas.

Gauta 2011 m. liepos 7 d.
Received on July 7, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 10, 2011

Corresponding author
Aistė Barbora Ušpurienė
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 61269645
E-mail a.b.uspuriene@gmail.com

DYNAMICAL PECULIARITIES OF CONCATENATIONAL CHANGES IN FUNCTIONAL CARDIOVASCULAR PARAMETERS

Eurelija Venskaitytė[1], Jonas Poderys[1], Tadas Česnaitis[2]
Lithuanian Academy of Physical Education[1], Kaunas, Lithuania
Lithuanian University of Health Sciences[2], Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Traditional time series analysis techniques, which are also used for the analysis of cardiovascular signals, do not reveal the relationship between the changes in the indices recorded associated with the multiscale and chaotic structure of the tested object, which allows establishing short-and long-term structural and functional changes.

Research aim was to reveal the dynamical peculiarities of interactions of cardiovascular system indices while evaluating the functional state of track-and-field athletes and Greco-Roman wrestlers.

Research methods. Twenty two subjects participated in the study, their average age of 23.5 ± 1.7 years. During the study standard 12 lead electrocardiograms (ECG) were recorded. The following ECG parameters were used in the study: duration of RR interval taken from the II standard lead, duration of QRS complex, duration of JT interval and amplitude of ST segment taken from the V standard lead.

Research results. Significant differences were found between inter-parametric connections of ST segment amplitude and JT interval duration at the pre and post-training testing. Observed changes at different hierarchical levels of the body systems revealed inadequate cardiac metabolic processes, leading to changes in the metabolic rate of the myocardium and reflected in the dynamics of all investigated interactions.

Discussion and conclusions. It has been found that peculiarities of the interactions of ECG indices interactions show the exposure of the functional changes in the body at the onset of the workload. The alterations of the functional state of the body and the signs of fatigue, after athletes performed two high intensity training sessions per day, can be assessed using the approach of the evaluation of interactions between functional variables. Therefore the evaluation of the interactions of physiological signals by using time series analysis methods is suitable for the observation of these processes and the functional state of the body.

Keywords: electrocardiogram, time series, functional state.

INTRODUCTION

Interactions of local complex adaptive system (CAS) components, which require exploring the processes of discovery and examination at a microscopic level, open the door to the global processes of the specific models or helps to predict the behavior of the global nature (Provata et al., 2008).

One or two digital time series contain information about the research object, and using certain mathematical methods this information can be expressed in the form of mathematical relationships. In this article we used analytical method developed by professor Z. Navickas and L. Bikulčienė (2008). This method enables the evaluation of the dynamic relationships of the ECG parameters cointegrating primary data series into the second order matrix.

Signal dynamic interactions, characterising individual systems, are very significant to functional analysis of the human body as CAS. Identification of parameters, method sensitivity analysis and the understanding the physiological significance of final results still remains an actual problem (Beckers et al., 2001; Batzel, Bachar, 2010). Non-linear mathematical analysis methods and application integration solving a range of medical and sports science problems can be some of those solutions.

The aim of the study was to reveal the dynamical peculiarities of interactions of cardiovascular system indices while evaluating the functional state of track-and-field athletes and greco-roman wrestlers.

RESEARCH METHODS

Twenty two subjects participated in this study, their average age was 23.5 ± 1.7 years. Further characterization of the subjects is presented in Table 1. The study was divided into two investigations. The first investigation was designed to analyse the peculiarities of concatenational changes in the functional parameters of the cardiovascular system of elite Greco-Roman wrestlers (n = 12), when two high-intensity training sessions per day were carried out (wrestlers performed a typical Rouffier exercise test in the 4 stages of the investigation protocol: on the 1st day before the training session, after the 1st and the 2nd training sessions, and on the 2nd day before the training session). The second investigation allowed exploring peculiarities of concatenational changes in the functional parameters of the cardiovascular system of track-and-field athletes and Greco-Roman wrestlers (n = 10) during a dosed exercise test (Rouffier test).

Table 1. **Characteristics of the subjects**

Investigations	Number of participants	Stature, cm	Weight, kg
Investigation 1 Elite Greco-Roman wrestlers	12	180.0 ± 2.22	87.7 ± 5.72
Investigation 2 Elite Greco-Roman wrestlers and track-and-field athletes	10	181.5 ± 0.94	78.0 ± 1.55

During all investigations standard 12 lead electrocardiograms (ECG) were recorded using computerized analysis program “Kaunas–Load” (Institute of Cardiology, KMU, Lithuania). Discriminants of the parameters calculated from the following ECG time series were as follows: duration of RR interval taken from the IInd standard lead, duration of QRS complex, duration of JT interval and amplitude of ST segment taken from the Vth standard lead.

The assessment of inter-parameter relationships obtained while monitoring vital signals was developed by Z. Navickas and L. Bikulčienė (2008). Two synchronous time series (xn : = 0, 1, 2,…) and (yn : = 0, 1, 2,…), which represent the ECG parameter measurements were structured and analysed using the numerical characteristics of the second order matrix (Formula 1) and the main components of it (Berškienė et al., 2009):

$$A_n := \begin{bmatrix} x_n & x_{n-1} - y_{n-1} \\ x_{n+1} - y_{n+1} & y_n \end{bmatrix} \quad (1)$$

The most informative characteristics rose from matrix definitions and they were discriminants (D) of matrix:

$$D\,A_n = ((x_n - y_n)2 + 4((x_{n-1} - y_{n-1}) * (x_{n+1} - y_{n+1}))) \quad (2)$$

Complexity measure reflecting the degree of coupling between heart electrophysiological variables was expressed as the value of D (see Formula 2). If the value of D decreases and is close to zero, the interaction between two synchronous numerical time series (ECG signals) increases, but the complexity of the adaptive system decreases.

A statistical difference was tested applying the nonparametric Mann-Whitney test for independent samples and the nonparametric Wilcoxson test for related samples (*SPSS for Windows 17.0*). The difference when p value was lower than 0.05 was regarded as statistically significant.

RESEARCH RESULTS

The concatenation of ST segment amplitude and JT interval duration analysis allowed indicating endogenous functional changes in heart (Figure 1). Statistically significant ($p < 0.05$) differences were indicated between pre and post-training testing. ST-segment and JT interval discriminant values in the range of change were much smaller compared to the higher fractal levels (systemic level and subsystemic level relating to the heart regulatory processes).

The analysis of the interactions of all investigated parameters showed that the fatigability enhanced fluctuations induced by dosed exercise test trials, and it increased respectively to the number of training sessions. These results confirm the dynamic sensitivity of the complex adaptive system to initial conditions and attractor distribution or transition from one attractor to another leading to fluctuation.

We also observed changes at different hierarchical levels of the body systems. These changes revealed inadequate cardiac metabolic processes, leading to changes in the metabolic rate of the myocardium and reflected in the dynamics of interactions. Such kind of the dynamic development of interactions indicates the occurrence of fatigue which is not observed at the systemic level (Figures 2 A and B).

Figure 1. **Dynamics of ST segment and JT interval interaction during Rouffier test before and after training sessions (subject M. E.)**

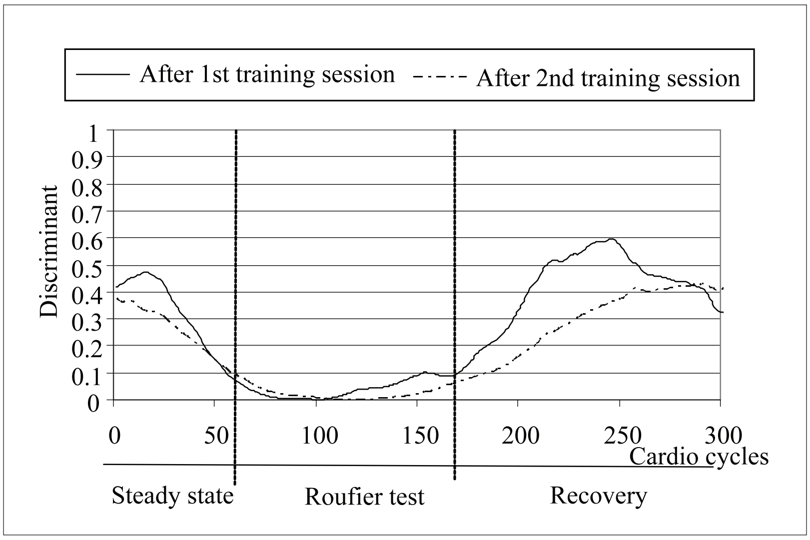
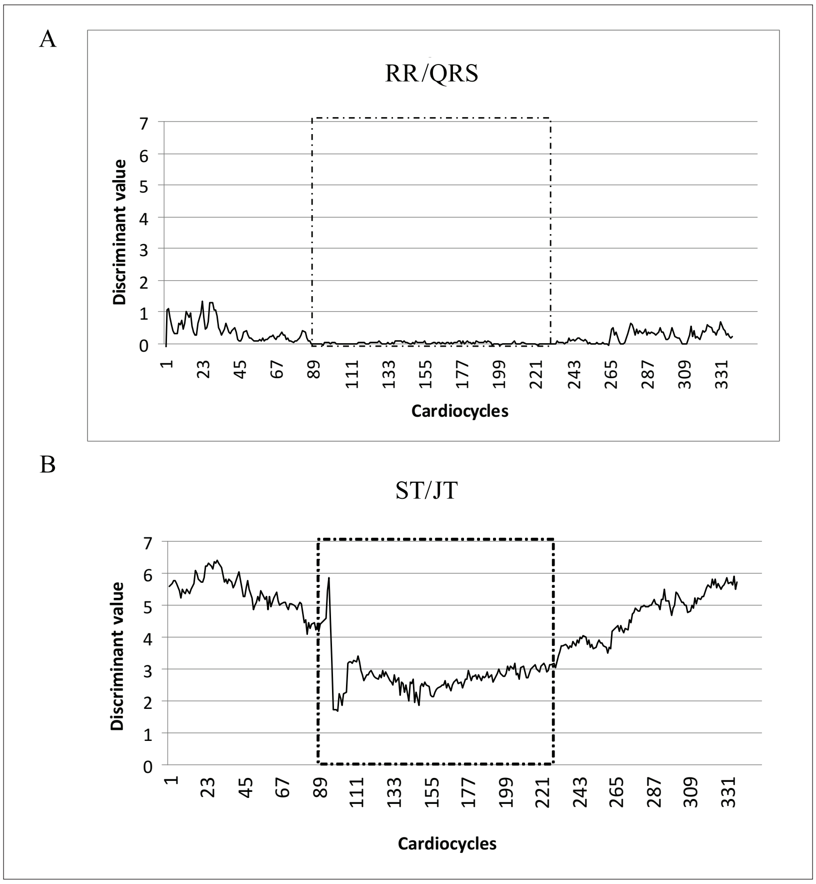


Figure 2. **Dynamics of RR interval and QRS complex interaction (systemic level – regulatory processes) (A) and concatenation of ST segment amplitude and JT interval duration (subsystemic level – cardiac metabolism processes) (B) during dosed exercise test (subject M. E.)**



Note. Dotted-line square indicates physical load during the exercise test.

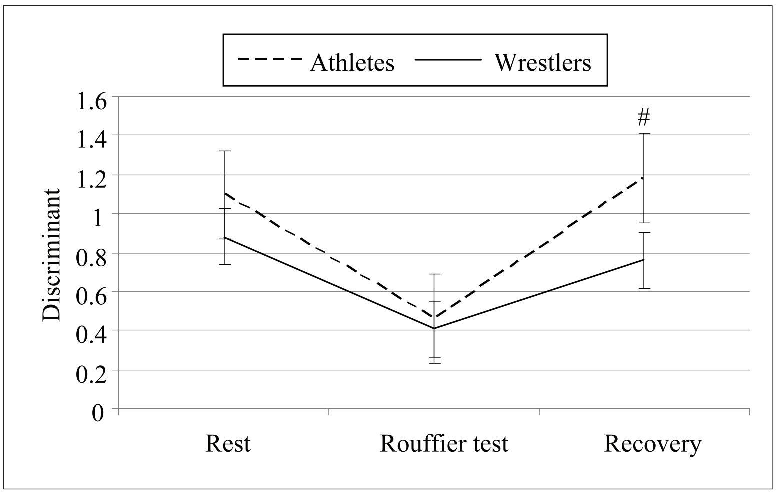


Figure 3. **Dynamics of QRS complex and JT interval interaction (subsystemic level–regulatory processes) during dosed exercise test**

Note. # – significant difference ($p < 0.05$) between groups.

Our results showed that the analysis of the alteration in cardiovascular functional parameters in the body readiness for the upcoming load starts even before the load begins and the performance is typical for each athlete (Figure 3). However, statistically significant difference ($p < 0.05$) was observed just at the recovery period.

DISCUSSION

The results of this study show that conventional Heuristic evaluation has proved to be less sensitive to relatively small changes in the evaluation of the functional state in terms of the body function inter-parametric links and their synergistic properties. Currently, the approach analysis – complexity – is becoming more and more popular (Rickards et al., 2010).

Elite Greco-Roman wrestlers who have two high-intensity training sessions per day have been studied in detail. This study sought to identify indicators of susceptibility to cardiovascular function and the wealth of information in assessing relatively small changes in the functional state (Krstacic et al., 2007). The overall effect of the influence of the functional state characteristics change because of fatigue changes at different levels of functional inter-parametric concatenations.

Statistically significant ($p < 0.05$) differences were found between inter-parametric connections of ST segment amplitude and JT interval duration at the pre and post-training testing. ST-segment and JT interval discriminant values in the range of change were much smaller compared to the higher fractal levels (systemic level and subsystemic level relating to the heart regulatory processes). These changes revealed inadequate cardiac metabolic processes leading to changes in the metabolic rate of the myocardium and reflected in the dynamics of interactions (Enoka, Duchateau, 2008; Šmidtaitė et al., 2009).

The last study analyzed the peculiarities of concatenational changes in the functional parameters of the cardiovascular system during dosed aerobic exercise test more precisely. It is known that the cerebral cortical motor centers of the signals at parallel with the motor impulses sent to muscles and autonomic nervous system, which reduces cardiac parasympathetic inhibition (Costa et al., 2008).

Track-and-field athletes exhibited lower degree perturbations than wrestlers ($p < 0.05$) in the period of body recovery, but an inverse dynamics of relationships was observed compared to the alteration of signal interactions before and during the exercise test. Corresponding oscillations were obtained during the analysis of different fractal levels (systemic, subsystemic) of the system (Peng et al., 2009; Šmidtaitė et al., 2009).

Likewise, in assessing functional fitness test results of the complex and the relative performance of high-performance athletes is better than Heuristic evaluation, and it allows the individual indicators reveal relatively small differences and changes in the individual skills of athletes and thus should be used for more sports studies. The obtained results of the exercise test enabled us to identify the dynamical changes of the independence of parameters, and analyse an opposite phenomenon – their interaction (Costa et al., 2008).

CONCLUSIONS AND PERSPECTIVES

1. Individual features are observed at different hierarchical levels of the body, therefore individual and all-levels observation scale involving evaluation enable a more detailed understanding of the functional characteristics of the body.

2. Evaluation of interaction changes in electrocardiographic parameters indicates that when the body starts the exercise, a natural preparation for the next workout is in progress.

REFERENCES

Batzel, J. J., Bachar, M. (2010). Modeling the cardiovascular-respiratory control system: Data, model analysis, and parameter estimation. *Acta Biotheory*, 58 (4), 369–380.

Beckers, F., Rameakers, D., Aubert, A. E. (2001). Approximate entropy of heart rate variability: Validation of methods and application in heart failure. *Cardiovascular Engineering*, 1, 177–182.

Berškienė, K. et al. (2009). Analysis of dynamical interrelations of electrocardiogram parameters. *Electronics and Electrical Engineering*, 7 (95), 95–98.

Costa, M. D., Peng, C. K., Goldberger, A. L. (2008). Multiscale analysis of heart rate dynamics: entropy and time irreversibility measures. *Cardiovascular Engineering*, 8, 88–93.

Enoka, R. M., Duchateau, J. (2008). Muscle fatigue: What, why and how it influences muscle function. *The Journal of Physiology*, 586, 11–23.

Krstacic, G., Krstacic, A., Smalcelj, M. A., Milicic, D., Jembrek-Gostovic, M. (2007). The Chaos Theory and Nonlinear Dynamics in Heart Rate Variability Analysis: Does it work in short – time Series in Patients with Coronary Heart Disease? *Annals of Non–invasive Electrocardiology*, 12 (2), 130–136.

Navickas, Z., Bikulčienė, L. (2008). Antros eilės matricų informatyvieji dėstiniai. *Matematika ir matematinis modeliavas*, 4, 26–33.

Peng, C. K., Costa, M., Goldberger, A. L. (2009). Adaptive data analysis of complex fluctuations in physiologic time series. *Advanced Adaptation Data Analysis*, 1 (1), 61–70.

Provata, A., Sokolov, I. M., Spagnolo, B. (2008). Ecological complex systems. *The European Physical Journal B*, 65, 307–314.

Rickards, C. A., Ryan, K. L., Convertino, V. A. (2010). Characterization of common measures of heart period variability in healthy human subjects: Implications for patient monitoring. *Journal of Clinical Monitoring and Computing.* 24, 61–70.

Šmidtaitė, R., Navickas, Z., Vainoras, A., Bikulčienė, L., Poškaitis, V. (2009). Evalutation of Coherence of T-Wave in Different Leads: Electronics and Electrical Engineering. *Technologija,* 5 (93), 113–116.

ŠIRDIES IR KRAUJAGYSLIŲ SISTEMOS FUNKCINIŲ RODIKLIŲ DINAMINIAI POKYČIAI

Eurelija Venskaitytė[1], Jonas Poderys[1], Tadas Česnaitis[2]
Lietuvos kūno kultūros akademija[1], Kaunas, Lietuva
Lietuvos sveikatos mokslų universitetas[2], Kaunas, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tradiciniai laiko eilučių analizės metodai, taikomi širdies ir kraujagyslių sistemos (ŠKS) signalams tirti, neatskleidžia registruojamų rodiklių tarpusavio sąsajų kaitos, susijusios su tiriamojo objekto daugiaskale struktūra ir chaotiškumu, kurie leidžia nustatyti trumpalaikius bei ilgalaikius nagrinėjamos sistemos struktūrinius, funkcinius pokyčius.

Tikslas: nustatyti širdies ir kraujagyslių sistemos funkcinių rodiklių sąsajų kaitos ypatumus vertinant lengvaatlečių ir graikų-romėnų imtynininkų organizmo būsenas.

Metodai. Tirti 22 graikų-romėnų imtynininkai ir lengvaatlečiai, kurių amžiaus vidurkis 23,5 ± 1,7 metų. Visų testavimų metu buvo registruojamos standartinės 12 derivacijų elektrokardiogramos (EKG). Buvo vertinama šių EKG rodiklių dinaminiai tarpusavio sąsajų pokyčiai: RR intervalo trukmė (II derivacija), QRS komplekso trukmė, JT intervalo trukmė ir ST segmento amplitudė (V derivacija).

Rezultatai. Reikšmingai skyrėsi ST segmento amplitudės ir JT intervalo trukmės tarpusavio sąsajų pokytis prieš pratybas ir po jų. Stebint įvairių organizmo sistemų pokyčius nustatyta nepakankama širdies metabolinė veikla, dėl kurios pakito miokardo medžiagų apykaita. Šias ypatybes parodė tirtų rodiklių sąsajų kaita.

Aptarimas ir išvados. EKG rodiklių sąsajų kaitos vertinimas atskleidė: dar prieš krūvį organizme vyksta funkciniai pokyčiai. Organizmo funkcinės būklės kaita ir nuovargio požymiai, sportininkams atliekant dvejas intensyvias pratybas per dieną, gali būti vertinami naudojant funkcinių rodiklių tarpusavio sąsajų kaitos vertinimo metodą. Šiuos pokyčius rodo skirtingų organizmo sistemų funkcijų lygmenų rodikliai, todėl individualus visų sistemų stebėjimas ir vertinimas leidžia pagerinti sportininkų treniruotės vyksmo eigą ir valdymą.

Raktažodžiai: elektrokardiograma, laiko eilutės, funkcinė būklė.

Gauta 2011 m. liepos 25 d.
Received on July 25, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Eurelija Venskaitytė**
Lithuanian Academy of Physical Education
Sporto str. 6, LT-44221 Kaunas
Lithuania
Tel +370 37 302650
E-mail evenskaityte@yahoo.com

ADJUSTING THE TRAINING PROCESS IN JUDO ACCORDING TO PHYSICAL AND FUNCTIONAL PARAMETERS

Giorgi Zubitashvili
Ilia State University, Tbilisi, Georgia

ABSTRACT

Research background and hypothesis. The specificity of the technical performance in judo demands from athletes to perform fast and powerful actions at a high level, therefore, much importance is given to the development of aerobic capacity and supporting motor system, in particular, strength of the hand-grip function.

Research aim was to study the judoka's hand-grip strength and lung vital capacity indices in the aspect of age and weight categories and find out the relation between those two factors as well as the most characteristic age period of motor development.

Research methods. The studies were carried out in the preparatory periods of 2009–2011 training cycles. The subjects were 2000 male judokas in 8 different weight categories. The measurements were made using a dynamometer and dry spirometer. The obtained results were statistically processed by SPSS 19, using ANOVA test.

Research results. Research results showed that the judoka's hand-grip and lung vital capacity average indices increased in each higher age and weight category, but this increase was not regular. The most obvious period of motor development at which increase in results was most noticeable was 13–15 years of age. The increase in the hand-grip strength and lung vital capacity in the age and weight categories were inversely proportional, and we found a correlation between them.

Discussion and conclusion. We suggest that there is a close relationship between motor system and the muscles participating in respiration.

Keywords: hand grip, lung vital capacity, data dynamics, practical use.

INTRODUCTION

Training judo athletes' motor skills and developing anthropometric qualities is different from those of untrained persons and representatives of other kinds of sports (Marchocka, 1992; Jagiełło, Kalina, 2007). These differences are mainly caused by the specific nature of training and skills developed in training sessions and due to the morphological changes in their bodies.

The judoka develops certain specific motor characteristics/skills at the very initial stage of training-learning process when the body is influenced by various exercises intended for general and special development (Zubitashvili, 2010).

In the judoka training process the greatest attention is paid to the development of fast and powerful motor skills, which implies synchronic development of strength and respiratory capacities. According to D. Chitashvili et al. (2010) from bio motor abilities, the development of hand grip strength is the priority; and aerobic capacity indicators are the increase in lung vital capacity.

Hand muscles, hand grip muscles in particular, participate in all manipulative activities realized by the cranial part of the body; thus they have a significant role in habitual, ordinary or specific professional work as well as in sport activities or in sport testing, talent selection or prognostic criteria. According to M. Dopsaj et al. (2007) and D. Leyk et al. (2007), hand grip strength is not always the same, along with gender and age it also depends on the specificity of the type of sports.

According of I. Banovic (2001), it is well known that persons under the experiment with more strength in hand muscles are more successful in wrestling because having strong hands they can block the opponent's offensive actions, control the space between themselves and the rival and manage to take more favorable positions for the realization of their own attack.

In judo, besides hand grip strength much attention is paid to the rational use of it in practice, in particular the correct hand-grip in order to take a favorable fighting position. According to J. Pedro (2001), judo is impossible without using stances and grips correctly. In addition, during all time of wrestling judoka has to fight continuously for taking the advantageous position for hand-grip.

It has been stated that the development of hand grip strength and aerobic capacity do not differ between elite and non-elite judokas (Franchini et al., 2005), but it is also obvious that their values are directly related to the quality of body working ability, being one of the most important conditions for success (Chitashvili, 2005). Despite the above described studies providing useful information, we still do not come across such complex problem resolution approaches which would be able to establish judokas' physical abilities and functional capacities (in our case, hand-grip strength and lung vital capacity) in the aspect of age and weight categories. This fact determined our goal.

Research aim was to study judoka's hand-grip strength and lung vital capacity indices in the aspect of age and weight categories and find out the relations between these two factors as well as the most characteristic age period of motor development.

The tasks of the research. Aiming at achieving this goal we have to solve the following tasks:

1. Establish the average indices of hand grip strength and lung vital, capacity compare them by age and weight categories and determine the age when the greatest results are observed.
2. Determine of possible correlations between the data.

RESEARCH METHODS

The subjects. The research was conducted during three identical preparation periods (2009–2011) of the training cycle for male judokas aged 8–20 years, training at 10 different sports schools of Georgia.

Experiment included the 2000 judokas from the total number of persons (2314) who were selected at random. They were in 8 different weight categories (20–30, 31–40, 41–50, 51–60, 61–70, 71–80, 81–90 and 91–100 kg). The sum of weight categories at all ages made 50. Each of them consisted of 40 judokas.

Distribution of judokas in the experiment by age and weight categories is provided in Table 1.

Measures. The hand-grip strength was measured in the dominating hand using the 90 kg scale dynamometer (# 13968). The persons under the experiment were given a task to squeeze the dynamometer with maximum capacity and show the maximal ability of hand grip.

Lung vital capacity was determined by dry spirometer (ТУ 64-1-2267-77). The persons under the experiment were given a task to exhale into the spirometer with their maximum capacity after taking a deep breath. The data from the persons under the experiment were obtained after finishing the first part of the exercise in standing position. Three attempts for each device were allowed, the best result was recorded.

The aforementioned research methods made it possible to study the indices of the judokas' hand-grip strength and the lung vital capacity by age and weight categories perfectly and to create the necessary numeral standards for identification of their athletic ability.

Statistics. Statistical analysis of the data was carried out by using the software package SPSS 19 for Windows. The ANOVA test was used to determine the effect of age (8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 years) and weight (20–30; 31–40; 41–50; 51–60; 61–70; 71–80; 81–90 and 91–100 kg) on hand grip strength and lung vital capacity. Descriptive data were presented as means, SD, Standard Error, Max and Min. The

Table 1. **Cross tabulation of age and weight categories**

Count		Weight categories								Total
		20–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	
Age	8	**40**	**40**	**40**	0	0	0	0	0	120
	9	**40**	**40**	**40**	0	0	0	0	0	120
	10	**40**	**40**	**40**	0	0	0	0	0	120
	11	0	**40**	**40**	**40**	0	0	0	0	120
	12	0	**40**	**40**	**40**	0	0	0	0	120
	13	0	**40**	**40**	**40**	**40**	0	0	0	160
	14	0	0	**40**	**40**	**40**	**40**	0	0	160
	15	0	0	0	**40**	**40**	**40**	**40**	0	160
	16	0	0	0	**40**	**40**	**40**	**40**	**40**	200
	17	0	0	0	**40**	**40**	**40**	**40**	**40**	200
	18	0	0	0	**40**	**40**	**40**	**40**	**40**	200
	19	0	0	0	0	**40**	**40**	**40**	**40**	160
	20	0	0	0	0	**40**	**40**	**40**	**40**	160
Total		120	240	280	320	320	280	240	200	2000

Note: The Judokas were involved in the learning-training process by the program approved by the National Federation of Judo of Georgia in 2008, in accordance with the admitted worldwide KIU program which serves harmonious development and professional formation to judokas *(Hence, certainty can be said that the training by aforementioned program in comparison with development of other characteristics does not cause any special increase in either the strength of hand-grip or lung vital capacity).*

level of significance was set at $p < 0.05$ (For detail sample size distribution see Tables 2 and 3).

In order to evaluate the relationship between the above mentioned variables, Pearson's coefficient of Bivariate correlation was calculated, test of significance was two tailed method (Table 4).

RESEARCH RESULTS

The indices of judokas' hand-grip strength (kg) and the lung vital capacity (Liters) by age and weight categories are provided in the Tables 2 and 3.

The obtained data are reported in Figures 1 and 2, reflecting the mean values of hand-grip strength and the lung vital capacity considering the age and weight categories.

In order to determine the possible correlation between the received data, as it was mentioned in "Statistics", Pearson's coefficient of Bivariate correlation was used. The data displayed in Table 4, indicate the reliable correlative affect on each other of the weight category, hand-grip strength and lung vital capacity increases.

DISCUSSION

The data obtained show that the average indices of strength of hand-grip and lung vital capacity increase with age and weight category of judokas (see Figures 1 and 2). Even in case of the same weight category, the greater the age of a judoka is, the higher the results are, though the results do not increase equally that would give the possibility to determine the stage of motor development.

In L. W. Wołkow's (1998) study concerning the aforementioned motor development stage three levels of children and young people's particular growth of physical capacities are identified: 8 – to 9 years, 10 – to 12 years and 13 – to 14 years of age.

According to the results obtained by W. Jagiełło et al. (2007), the most effective period for motor development of young male judokas is 14–15 years of age. Instead, in our data we observed one especially distinguished level of motor development. Its range is relatively wide, and it covers 13–15 years of age, which should be conditioned by the tested persons' involvement in sports, particularly in judo and as a result of prolonged phase of motor development, which is clearly seen in Figures 1 and 2. The same figures show that hand-grip strength and lung vital capacity increase almost equally with age and weight category. Besides visual effects noticed in figures, the reliability of this fact is also proved by the data in Table 4, where the correlation accuracy between them is over 95%.

CONCLUSIONS AND PERSPECTIVES

Even at the level of the age and weight categories there is a close relation between motor system and respiratory muscles, and it is desirable to take this fact into account in planning the learning-training process in order to facilitate the creation of equal

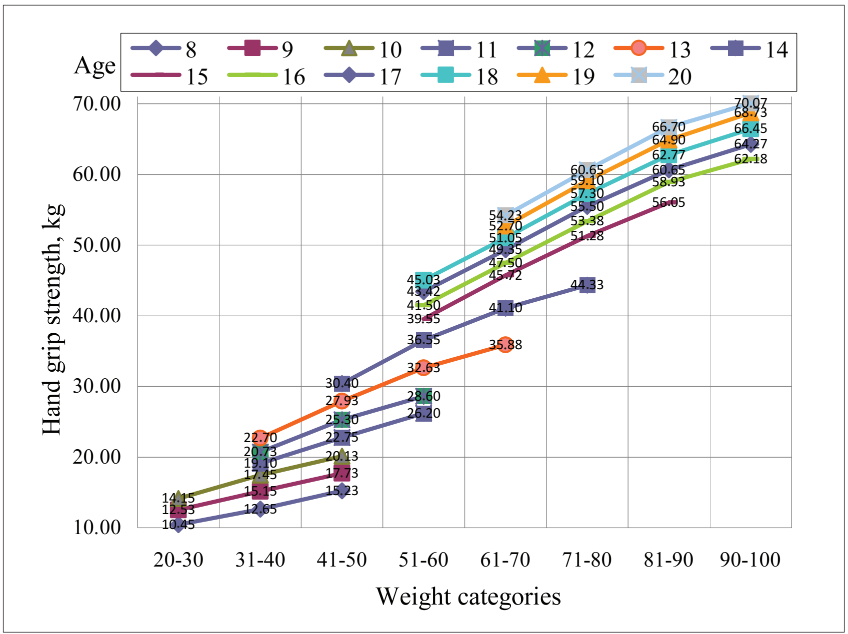


Figure 1. **The mean value of hand grip strength in different age and weight categories of judokas**

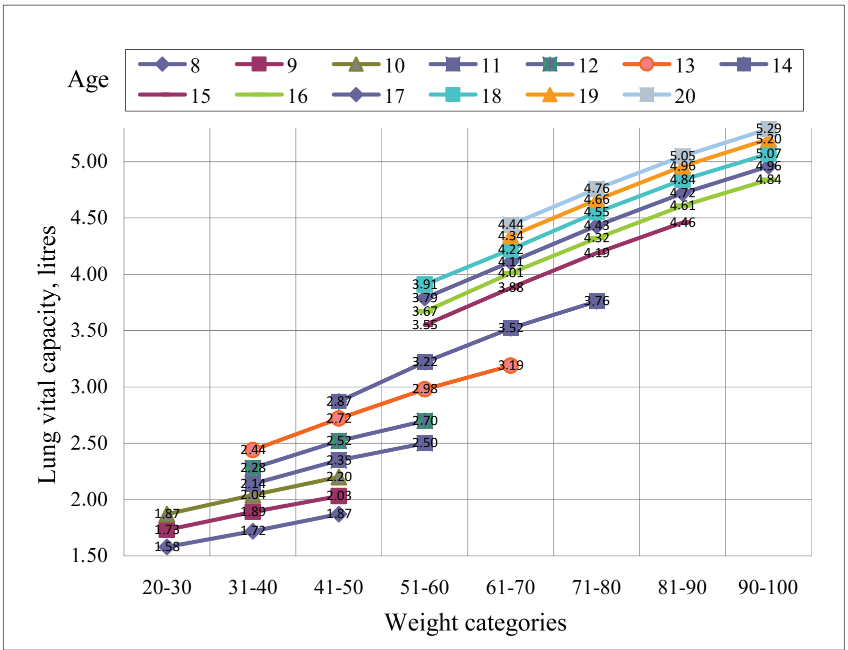


Figure 2. **The mean value of lung vital capacity in different age and weight categories of judokas**

preconditions for the physical and functional development of the body.

The research results will find their application in practical activities, if we compare the individual judokas' results with those obtained by us.

It has become possible to determine the rate of future physical and functional development for judokas of different age and weight categories in advance, being an important precondition for the regulation of learning-training process.

Based on the results of the research, promising judokas, training in different regions of Georgia were revealed, their data were passed over to the leading coaches, and they were recommended for individual training because of their high athletic abilities.

Further research should continue to identify the mean, maximum and minimum growth rates of cognitive processes as well. It would probably make it even easier to manage judoka's training which involves the development of physical, functional and cognitive abilities at each period of age.

Acknowledgements. In the process of research technical support was given by the Georgian Judo Federation.

Table 2. **Descriptive data of hand grip considering age and weight categories of judokas**

Age	N	Weight of judokas, kg		Weight categories (kg)/minimum and maximum for 'weight of judokas'											
		Mean	Std. Deviation	20–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100				
				Hand grip strength, kg											
				Mean								Std. Deviation	Std. Error	Minimum	Maximum
8	40	25.35	2.547	10.45								2.572	0.407	6	15
8	40	34.28	2.075		12.65							3.034	0.48	7	18
8	40	44.3	2.115			15.23						3.69	0.583	8	22
9	40	25.18	3.054	12.53								2.611	0.413	8	17
9	40	34.18	2.183		15.15							2.905	0.459	9	20
9	40	44.88	2.388			17.73						4.006	0.633	10	25
10	40	24.65	3.06	14.15								2.914	0.461	9	19
10	40	34.67	2.712		17.45							3.396	0.537	11	23
10	40	45.6	2.845			20.13						4.127	0.653	13	28
11	40	35.45	2.81		19.1							3.35	0.53	13	25
11	40	45.4	2.96			22.75						5.237	0.828	15	31
11	40	54.58	2.581				26.2					5.205	0.823	18	34
12	40	36.08	2.759		20.73							3.457	0.547	14	27
12	40	44.2	2.377			25.3						5.175	0.818	17	33
12	40	55.15	2.527				28.6					5.606	0.886	20	37
13	40	34.33	2.536		22.7							3.299	0.522	16	29
13	40	46.32	2.712			27.93						4.526	0.716	20	36
13	40	54	2.449				32.63					5.873	0.929	23	41
13	40	66.28	2.65					35.88				5.501	0.87	26	47
14	40	45.38	2.844			30.4						5.372	0.849	22	38
14	40	56.38	2.192				36.55					5.657	0.894	27	45
14	40	64.25	2.307					41.1				5.606	0.886	31	52
14	40	76.07	2.358						44.33			7.109	1.124	32	57
15	40	56.15	3.167				39.55					6.243	0.987	29	49
15	40	65.4	2.509					45.72				5.853	0.925	35	56
15	40	74.25	2.436						51.28			8.003	1.265	39	63
15	40	85.45	2.736							56.05		7.916	1.252	43	69
16	40	54.27	2.522				41.5					6.106	0.965	31	51
16	40	66.6	2.725					47.5				4.466	0.706	37	58
16	40	75.15	2.597						53.38			6.927	1.095	42	66
16	40	86.02	2.796							58.93		7.627	1.206	46	72
16	40	95.05	2.736								62.18	8.048	1.272	50	76
17	40	55.75	2.447				43.42					5.813	0.919	34	53
17	40	67.62	2.261					49.35				4.594	0.726	39	60
17	40	75.95	2.791						55.5			7.042	1.113	44	69
17	40	85.68	2.777							60.65		8.502	1.344	48	74
17	40	95.65	2.527								64.27	8.286	1.31	52	78
18	40	56.33	2.117				45.03					5.673	0.897	36	54
18	40	66.58	2.659					51.05				5.233	0.827	41	62
18	40	75.62	2.761						57.3			8.156	1.29	46	71
18	40	85.88	2.503							62.77		8.094	1.28	51	77
18	40	95.57	2.438								66.45	7.449	1.178	54	80
19	40	66.43	2.716					52.7				5.18	0.819	42	64
19	40	75.3	2.633						59.1			7.725	1.221	47	73
19	40	85.1	2.458							64.9		8.351	1.32	53	79
19	40	96.37	2.404								68.73	7.261	1.148	56	82
20	40	66.95	2.32					54.23				5.299	0.838	43	65
20	40	75.58	2.48						60.65			7.181	1.135	48	74
20	40	86.55	2.396							66.7		7.819	1.236	54	80
20	40	95.43	2.395								70.07	6.746	1.067	58	84

Table 3. **Descriptive data of lung vital capacity considering age and weight categories of judokas**

Age	N	Weight of judokas, kg		Weight categories (kg) / minimum and maximum for 'weight of judokas'											
		Mean	Std. Deviation	20–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100				
				Lung vital capacity, litres											
				Mean								Std. Deviation	Std. Error	Minimum	Maximum
8	40	25.35	2.547	1.58								0.219	0.035	1.1	2
8	40	34.28	2.075		1.72							0.223	0.035	1.2	2.1
8	40	44.3	2.115			1.87						0.221	0.035	1.4	2.3
9	40	25.18	3.054	1.73								0.205	0.032	1.3	2.1
9	40	34.18	2.183		1.89							0.253	0.04	1.4	2.3
9	40	44.88	2.388			2.03						0.236	0.037	1.6	2.5
10	40	24.65	3.06	1.87								0.263	0.042	1.5	2.3
10	40	34.67	2.712		2.04							0.31	0.049	1.5	2.5
10	40	45.6	2.845			2.2						0.283	0.045	1.7	2.7
11	40	35.45	2.81		2.14							0.295	0.047	1.7	2.6
11	40	45.4	2.96			2.35						0.326	0.052	1.8	2.9
11	40	54.58	2.581				2.5					0.358	0.057	1.9	3.1
12	40	36.08	2.759		2.28							0.304	0.048	1.8	2.8
12	40	44.2	2.377			2.52						0.31	0.049	1.9	3
12	40	55.15	2.527				2.7					0.317	0.05	2.1	3.3
13	40	34.33	2.536		2.44							0.299	0.047	1.9	2.9
13	40	46.32	2.712			2.72						0.347	0.055	2.1	3.3
13	40	54	2.449				2.98					0.321	0.051	2.3	3.6
13	40	66.28	2.65					3.19				0.421	0.067	2.5	3.9
14	40	45.38	2.844			2.87						0.352	0.056	2.2	3.5
14	40	56.38	2.192				3.22					0.321	0.051	2.6	3.9
14	40	64.25	2.307					3.52				0.543	0.086	2.7	4.4
14	40	76.07	2.358						3.76			0.59	0.093	2.8	4.8
15	40	56.15	3.167				3.55					0.416	0.066	2.8	4.3
15	40	65.4	2.509					3.88				0.564	0.089	2.9	4.7
15	40	74.25	2.436						4.19			0.574	0.091	3.2	5.2
15	40	85.45	2.736							4.46		0.596	0.094	3.4	5.5
16	40	54.27	2.522				3.67					0.529	0.084	2.9	4.5
16	40	66.6	2.725					4.01				0.503	0.08	3	4.9
16	40	75.15	2.597						4.32			0.578	0.091	3.3	5.3
16	40	86.02	2.796							4.61		0.621	0.098	3.5	5.6
16	40	95.05	2.736								4.84	0.777	0.123	3.7	6.1
17	40	55.75	2.447				3.79					0.504	0.08	3	4.6
17	40	67.62	2.261					4.11				0.462	0.073	3.1	5.1
17	40	75.95	2.791						4.43			0.548	0.087	3.4	5.4
17	40	85.68	2.777							4.72		0.614	0.097	3.6	5.8
17	40	95.65	2.527								4.96	0.75	0.119	3.8	6.2
18	40	56.33	2.117				3.91					0.457	0.072	3.1	4.7
18	40	66.58	2.659					4.22				0.453	0.072	3.2	5.2
18	40	75.62	2.761						4.55			0.612	0.097	3.5	5.6
18	40	85.88	2.503							4.84		0.632	0.1	3.7	6
18	40	95.57	2.438								5.07	0.724	0.114	3.9	6.3
19	40	66.43	2.716					4.34				0.375	0.059	3.3	5.3
19	40	75.3	2.633						4.66			0.585	0.093	3.6	5.7
19	40	85.1	2.458							4.96		0.8	0.126	3.8	6.2
19	40	96.37	2.404								5.2	0.671	0.106	4	6.4
20	40	66.95	2.32					4.44				0.392	0.062	3.4	5.4
20	40	75.58	2.48						4.76			0.552	0.087	3.7	5.8
20	40	86.55	2.396							5.05		0.648	0.102	3.9	6.3
20	40	95.43	2.395								5.29	0.644	0.102	4.1	6.5

Table 4. **Correlations of weight, hand grip strength and lung vital capacity**

		Weight category	Hand grip	Lung vital capacity
Weight category	Pearson Correlation	1	0.934(**)	0.902(**)
	Sig. (2-tailed)		0.000	0.000
	N	2000	2000	2000
Hand grip	Pearson Correlation	0.934(**)	1	0.976(**)
	Sig. (2-tailed)	0.000		0.000
	N	2000	2000	2000
Lung vital capacity	Pearson Correlation	0.902(**)	0.976(**)	1
	Sig. (2-tailed)	0.000	0.000	
	N	2000	2000	2000

Note. ** – correlation is significant at the 0.01 level (2-tailed).

REFERENCES

Banovic, I. (2001). Possible judo performance prediction based on certain motor abilities and technical knowledge (skills) assessment. *Kinesiology (Zagreb),* 33 (2), 191–206.

Chitashvili, D. (2005). *Kardio-respiratoruli da kuntovani sistemebis funqcionireba fizikuri datvirtvebis dros.* Tbilisi: Mecniereba.

Chitashvili, D., Zubitashvili, G., Korinteli, E. (2010). Bavshvta sportuli proforientaciis kriteriumebi. *Saqartvelos mecnierebata erovnuli akademiis macne (biomedicinis seria),* 36 (5–6), 373–380.

Dopsaj, M., Koropanovski, N., Vubkovic, G. et al. (2007). Maximal isometric hand grip force in well-trained university students in Serbia: Descriptive, functional and sexual dimorphic model. *Serbian Journal of Sports Sciences,* 1 (4), 138–147.

Franchini, E., Takito, M. Y., Kiss, M. et al. (2005). Physical fitness and anthropometrical differences between elite and non-elite judo players. *Biology of Sport,* 22 (4), 315–328.

Jagiełło, W., Kalina, R. M. (2007). Properties of motor development in young judokas. *Journal of Human Kinetics,* 17, 113–120.

Leyk, D., Gorges, W., Ridder, D. et al. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European Journal of Applied Physiology,* 99 (4), 415–421.

Marchocka, M. (1992). La costituzione fisica e strutturale del judoka. *Athlon (Roma),* 3, 41–45.

Pedro, J. (2001). *Judo Techniques & Tactics.* United States: Human Kinetics.

Wołkow, L. W. (1998). *Sportiwnaja podgotowka dietiej i podrostkow.* Kijów: Wieża.

Zubitashvili, G. (2010). Sacvrtno procesis regulireba. *Saqartvelos ganatlebis mecnierebata akademiis moambe,* 11, 167–172.

DZIUDO TRENIRUOTĖS VYKSMO REGULIAVIMAS PAGAL FIZINIUS IR FUNKCINIUS RODIKLIUS

Giorgi Zubitashvili
Ilia valstybinis universitetas, Tbilisis, Gruzija

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Dziudo technikos specifika reikalauja, kad būtų atliekami labai meistriški, greiti ir galingi judesiai, todėl labai svarbu ugdyti sportininkų aerobinį pajėgumą bei judamąją sistemą, ypač plaštakų jėgą.

Tikslas: ištirti dziudo imtynininkų plaštakų jėgą, plaučių gyvybinį pajėgumą amžiaus bei svorio kategorijų požiūriu ir nustatyti tinkamiausią amžių šioms savybėms ugdyti.

Metodai. Tyrimai buvo atliekami per pratybas 2009–2011 m. ciklo metu. Tirta 2000 vyrų – 8-ių svorio kategorijų dziudo imtynininkų. Matavimai buvo atliekami dinamometru ir spirometru. Gauti rezultatai apdoroti *SPSS 19* statistine programa taikant dispersinės analizės metodą.

Rezultatai. Vidutiniai plaštakų jėgos ir plaučių gyvybinio pajėgumo rodikliai su amžiumi ir kintant svorio kategorijai didėjo, tačiau nereguliariai. Geriausias judamojo aparato augimo laikotarpis yra 13–15 metų amžius – tada pasiekiama geriausių sportinių rezultatų. Aptiktas koreliacinis ryšys tarp plaštakų jėgos ir plaučių gyvybinio pajėgumo rodiklių.

Aptarimas ir išvados. Tarp sportininko judamosios sistemos ir raumenų, dalyvaujančių kvėpavimo procese, yra glaudus ryšys.

Raktažodžiai: plaštakos jėga, plaučių gyvybinis tūris, duomenų kaitumas, praktinė vetrė.

Gauta 2011 m. liepos 21 d.
Received on July 21, 2011

Priimta 2011 m. rugsėjo 9 d.
Accepted on September 9, 2011

Corresponding author **Giorgi Zubitashvili**
Ilia State University
Kakutca Cholokashvili Ave., 3/5, Tbilisi 0162
Georgia
Tel 599 47 90 75
E-mail g.zubitashvili@iliauni.edu.ge

REIKALAVIMAI AUTORIAMS

1. Bendroji informacija

1.1 Žurnale spausdinami originalūs straipsniai, kurie nebuvo skelbti kituose mokslo leidiniuose (išskyrus konferencijų tezių leidiniuose). Mokslo publikacijoje skelbiama medžiaga turi būti nauja, teisinga, tiksli (eksperimento duomenis galima pakartoti, jie turi būti įvertinti), aiškiai ir logiškai išanalizuota bei aptarta. Pageidautina, kad publikacijos medžiaga jau būtų nagrinėta mokslinėse konferencijose ar seminaruose.

1.2. Originalių straipsnių apimtis – iki 10, apžvalginių – iki 20 puslapių. Autoriai, norintys spausdinti apžvalginius straipsnius, jų anotaciją turi iš anksto suderinti su Redaktorių kolegija.

1.3. Straipsniai skelbiami anglų kalba su išsamiomis santraukomis anglų ir lietuvių kalbomis.

1.4. Straipsniai recenzuojami. Kiekvieną straipsnį recenzuoja du Redaktorių kolegijos nariai arba jų parinkti recenzentai.

1.5. Autorius (recenzentas) gali turėti slaptos recenzijos teisę. Dėl to jis įspėja vyriausiąjį redaktorių laiške, atsiųstame kartu su straipsniu (recenzija).

1.6. Du rankraščio egzemplioriai ir CD diskas siunčiami žurnalo „Ugdymas. Kūno kultūra. Sportas“ Redaktorių kolegijos atsakingajai sekretorei šiais adresais:

Žurnalo „Ugdymas. Kūno kultūra. Sportas“ atsakingajai sekretorei Daliai Mickevičienei

Lietuvos kūno kultūros akademija, Sporto g. 6, LT-44221 Kaunas

E-mail *zurnalas@lkka.lt*

1.7. Žinios apie visus straipsnio autorius. Būtina pateikti garantinį raštą, patvirtinantį, kad straipsnis yra originalus ir niekur kitur nepublikuotas.

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

2. Straipsnio struktūros reikalavimai

2.1. **Titulinis lapas.** Pateikiamas straipsnio pavadinimas, autorių vardai ir pavardės, darbovietės, nurodomas adresas susirašinėti.

2.2. **Santrauka.** Santraukoje (250 žodžių) svarbu atskleisti mokslinę problemą, jos aktualumą, tyrimo tikslus, uždavinius, metodus, pateikti pagrindinius tyrimo duomenis, jų aptarimą (lyginant su kitų autorių tyrimų duomenimis), išvadas. Santraukoje turi būti išskirti tokie poskyriai: Tyrimo pagrindimas ir hipotezė. Tikslas. Metodai. Rezultatai. Aptarimas ir išvados.

2.3. **Raktažodžiai.** 3–5 informatyvūs žodžiai ar frazės (negali būti nė vieno žodžio, esančio pavadinime).

2.4. **Įvadas.** Jame nurodoma tyrimo problema, jos ištirtumo laipsnis, sprendimo naujumo argumentacija (teorinių darbų), pažymimi svarbiausi tos srities mokslo darbai, tyrimo tikslas, objektas ir originali hipotezė.

2.5. **Metodika.** Šioje dalyje turi būti pagrįstas konkrečios metodikos pasirinkimas. Būtina aiškiai apibūdinti tiriamuosius, tyrimo metodų procedūras ir tyrimo eigą. Jei taikomi tyrimo metodai nėra labai paplitę ar pripažinti, reikia nurodyti priežastis, skatinusias juos pasirinkti. Aprašomi originalūs metodai arba pateikiamos nuorodos į literatūroje aprašytus standartinius metodus, nurodoma aparatūra (jei ji naudojama). Būtina nurodyti naudotus matematinės statistikos metodus (statistinį patikimumą, statistinę galią, pasikliautinąjį intervalą, dydžio efektą), paaiškinti, kaip buvo pasirinktas imties kiekis. Tyrimo metodai ir organizavimas turi būti aiškiai ir logiškai išdėstyti. Straipsnyje neturi būti informacijos, pažeidžiančios tiriamų asmenų anonimiškumą. Žmonių tyrimai turi būti atlikti remiantis Helsinkio deklaracijos principais.

2.6. **Tyrimo rezultatai.** Rezultatai turi būti pateikiami glaustai, nuosekliai ir logiškai nekartojant metodikos, pažymimas jų statistinis patikimumas ir galingumas. Šiame skyriuje nerekomenduojama aptarti tyrimo rezultatų. Rekomenduojame duomenis pateikti ne lentelėse, bet grafikuose.

2.7. **Rezultatų aptarimas.** Aptarimo pradžioje rekomenduojame pateikti pagrindinius originalius straipsnio teiginius (išvadas), kilusius iš tyrimo duomenų. Rezultatų aptarimą būtina struktūrizuoti išskiriant potemes (kiekvieną originalų atrastą teiginį rekomenduojame aptarti atskira poteme). Tyrimo rezultatai ir išvados lyginami su kitų autorių skelbtais duomenimis, įvertinami jų tapatumai ir skirtumai. Ypač svarbu pabrėžti tyrimo duomenų originalumą. Reikia vengti kartoti tuos faktus, kurie pateikti tyrimų rezultatų dalyje.

2.8. **Išvados ir perspektyvos.** Išvados turi būti formuluojamos aiškiai ir logiškai, vengiant tuščiažodžiavimo. Išvados turi būti pagrįstos tyrimo rezultatais ir patvirtinti arba paneigti tyrimo hipotezę. Svarbiausias išvadų reikalavimas – jos turi būti pasaulyje originalios. Būtina nurodyti tolesnių tyrimų perspektyvas.

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

2.10. **Literatūra.** Cituojami tik publikuoti mokslo straipsniai ir monografijos (išimtis – apgintų disertacijų rankraščiai). Į sąrašą įtraukiami tik tie šaltiniai, į kuriuos yra nuorodos straipsnio tekste. Mokslinio straipsnio literatūros sąrašas neturėtų viršyti 20 šaltinių, apžvalginio – 30.

3. Straipsnio įforminimo reikalavimai

3.1. Straipsnio tekstas turi būti išspausdintas kompiuteriu vienoje standartinio A4 formato (210 × 297 mm) balto popieriaus lapo pusėje, intervalas tarp eilučių 6 mm (1,5 intervalo), šrifto dydis 12 pt. Paraštės: kairėje – 3 cm, dešinėje – 1,5 cm, viršuje ir apačioje po 2,5 cm. Puslapiai numeruojami apatiniame dešiniajame krašte, pradedant tituliniu puslapiu, kuris pažymimas pirmu numeriu (1).

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

3.3. Tituliniame straipsnio lape pateikiama: a) trumpas ir informatyvus straipsnio pavadinimas (ne daugiau kaip 80); b) autorių vardai ir pavardės; c) institucijos, kurioje atliktas tyrimas, pavadinimas; d) autoriaus, atsakingo už korespondenciją, susijusią su pateiktu straipsniu, vardas, pavardė, adresas, telefono numeris, elektroninio pašto adresas. Jei autorius nori turėti slaptos recenzijos teisę, pridedamas antras titulinis lapas, kuriame nurodomas tik straipsnio pavadinimas. Tituliniame lape turi būti visų straipsnio autorių parašai.

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

3.5. Lentelė (pageidautina ne daugiau kaip 3–4 lent.) turi turėti eilės numerį (numeruojama ta tvarka, kuria pateikiamos nuorodos tekste) ir trumpą antraštę. Visi paaiškinimai turi būti straipsnio tekste arba trumpame prieraše, išspausdintame po lentele. Lentelėse vartojami simboliai ir sutrumpinimai turi sutapti su vartojamais tekste. Lentelės vieta tekste turi būti nurodyta kairėje paraštėje (pieštuku).

3.6. Paveikslai (pageidautina ne daugiau kaip 4–5 pav.) sužymimi eilės tvarka arabiškais skaitmenimis. Pavadinimas rašomas po paveikslu, pirmiausia pažymint paveikslo eilės numerį, pvz.: 1 pav. Paveikslo vieta tekste turi būti nurodyta kairėje paraštėje (pieštuku). Paveikslus prašytume pateikti atviru formatu (kad būtų galima redaguoti).

3.7. Literatūros sąraše šaltiniai nenumeruojami ir vardijami lotynų abėcėlės tvarka pagal pirmojo autoriaus pavardę. Pirma vardijami šaltiniai lotyniškais rašmenimis, paskui — rusiškais. Pateikiant žurnalo (mokslo darbų) straipsnį, turi būti nurodoma: a) autorių pavardės ir vardų inicialai (po pavardės); b) žurnalo išleidimo metai; c) tikslus straipsnio pavadinimas; d) pilnas žurnalo pavadinimas; e) žurnalo tomas, numeris; f) atitinkami puslapių numeriai. Jeigu straipsnio autorių daugiau kaip penki, pateikiamos tik pirmų trijų pavardės priduriant „et al.“, „ir kt.“, „и др.“

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

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

Literatūros aprašo pavyzdžiai:

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

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

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

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

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

Valiulytė, I. (2000). Išlaidos krašto apsaugai, jų pagrįstumas ir tikslingumas. *Sociumas,* vasaris. [2001 12 12]. Prieiga internetu: http://www.sociumas.lt/lit/nr12/krasto_apsauga.asp

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

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

INFORMATION TO AUTHORS

1. General information

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

1.2. Original articles (manuscripts) are up to 10 printed pages, review articles (manuscripts) – up to 20 printed pages. Authors who wish to submit a review article should correspond with the Editorial Board regarding the appropriateness of the proposed topic and submit a synopsis of their proposed review before undertaking preparation of the manuscript.

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

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

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

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

Dalia Mickevičienė, Executive Secretary of the Journal "Education. Physical Training. Sport"

Lithuanian Academy of Physical Education, Sporto str. 6, LT-44221, Kaunas, LITHUANIA

E-mail *zurnalas@lkka.lt*

1.7. Data about all the authors of the article (address, e-mail, fax and phone number, research interests of the authors) should be presented, as well as a guarantee letter proving that the article submitted is original and not previously published.

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

2. Requirements for the structure of the article

2.1. **The title page** contains the title of the article; the authors' names and surnames; the names of the institutions where the authors work or study (indicating the city and the country); the address for correspondence.

2.2. **The abstract** (250 words) is given in English and Lithuanian. It is important to reveal the scientific problem, its topicality, the aims of the research, its objectives, methods, to provide major data of the research, its discussion (in comparison with the research data of other authors) and conclusions. The abstract should be structured into the following sections: Research background and hypothesis. Research aim. Research methods. Research results. Discussion and conclusions.

2.3. **Keywords:** from 3 to 5 informative words and / or phrases (they should not appear in the title of the article).

2.4. **Introduction**. It should contain a clear statement of the problem of the research, the extent of its solution, the new arguments for its solution (for theoretical papers), most important papers on the subject, the aim, the object and the original hypothesis of the study.

2.5. **Research methods.** In this part the choice of specific methods of the research should be grounded. The research participants, methods, apparatus and procedures should be identified in sufficient detail. If the methods of the research used are not well known and widely recognized the reasons for the choice of a particular method should be stated. References should be given for all non-standard methods used. Appropriate statistical analysis should be performed based upon the experimental design carried out. It is necessary to indicate the methods of mathematical statistics applied (statistical reliability, statistical power, confidence interval, effect size), and to explain the estimation of the sample size. Do not include information that will identify human subjects. Research involving human subjects should be carried out following the principles of the Declaration of Helsinki.

2.6. **Research results.** Findings of the study should be presented concisely, consistently and logically, not repeating the chosen methods. The statistical significance and statistical power of the finding should be denoted. We recommend presenting the data in diagrams and not in tables.

2.7. **Discussion.** At the beginning of the discussion section the authors should provide major original research statements (conclusions) that are supported by the data. We recommend structuring the discussion of the findings into subsections (each original research finding should be discussed in a different subsection). The data and the conclusions of the research are compared to the data obtained by other researchers evaluating their similarities and differences. Authors should emphasize the original and important features of the study and avoid repeating all the data presented within the results section.

2.8. **Conclusions and perspectives.** The conclusions provided should be formulated clearly and logically avoiding excessive verbiage. Conclusions supported by the research results should confirm or reject the research hypothesis. The most important requirement for the research conclusions is their originality in the world. It is necessary to indicate the further perspectives of the research.

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).

2.10. **References.** Only published materials (with the exception of dissertations) and sources referred to in the text of the article should be included in the list of references. There should not be more than 20 references for original investigations and 30 references for review articles.

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.

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

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.

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

3.5. Every table (no more than three – four tables are recommended) should have a short subtitle with a sequential number given above the table (the tables are numbered in the same sequence as that of references given in the text). All explanations should be in the text of the article or in a short footnote added to the table. The symbols and abbreviations given in the tables should coincide with the ones used in the text. The location of the table should be indicated in the left-hand margin (in pencil).

3.6. All figures (no more than four-five figures) are to be numbered consecutively giving the sequential number in Arabic numerals, e. g. Figure 1. The location of the figure should be indicated in the left-hand margin of the manuscript (in pencil). The figures should be presented in open file formats so that they could be edited.

3.7. References should be listed in alphabetical order taking account of the first author. First the references in Latin characters are given, then – in Russian (Cyrillic) characters. For journal (research) articles the following information should be included: a) author names (surnames followed by initials), b) the date of publication, c) the title of the article with the same spelling and accent marks as in the original, d) the journal title in full, e) the volume number, f) inclusive page numbers. When five or more authors are named, list only the first three adding "et al."

For books the chapter title, chapter authors, editors of the book, publisher's name and location (institution, city) should be also included.

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

Examples of the correct format are as follows:

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

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

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

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

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.

LITHUANIAN ACADEMY OF PHYSICAL EDUCATION

BALTIC SPORT SCIENCE SOCIETY

DEPARTMENT OF PHYSICAL EDUCATION AND SPORT UNDER THE GOVERNMENT OF THE REPUBLIC OF LITHUANIA

LITHUANIAN NATIONAL OLYMPIC COMMITTEE

THE 5-th BALTIC SPORT SCIENCE CONFERENCE

CURRENT ISSUES AND NEW IDEAS IN SPORT SCIENCE

18–19 April, 2012

Kaunas, Lithuania

AIM OF THE CONFERENCE

The aim of the conference is to discuss the most recent advancements in the area of sport, physical education and health in the context of current global processes.

CONFERENCE MAIN TOPICS

√ Social and psychological aspects of physical education
√ Coaching science
√ Physical activity and health
√ Adapted physical activity, rehabilitation and social inclusion of the disabled
√ Biomedical engineering for sports
√ Tourism and sport management
√ Exercise physiology and motor control

KEYNOTE SPEAKERS

Prof. **Mark WILLIAMS**
Sport Sciences Institute of Liverpool University, United Kingdom
BECOMING SKILLED: ENVIRONMENTAL INFLUENCES ON THE DEVELOPMENT OF EXPERTISE IN SPORT

Prof. **Hakan WESTERBLAD**
Karolinska Institute, Stockholm, Sweden
MECHANISMS OF SKELETAL MUSCLE FATIGUE

Nuoširdžiai sveikiname!

Congratulations!

Lietuvos kūno kultūros akademijos doktorantę **Kristiną Zaičenkovienę**, 2011 m. birželio 23 d. Lietuvos kūno kultūros akademijoje apgynusią biomedicinos mokslų (biologijos) daktaro disertaciją tema „Ekscentrinio koncentrinio prieškrūvio liekamasis poveikis aerobiniam pajėgumui ir raumenų elektriniam aktyvumui bėgant skirtingu greičiu".
Mokslinis vadovas prof. dr. Arvydas Stasiulis.

We congratulate **Kristina Zaičenkovienė**, the student of doctoral studies at the Lithuanian Academy of Physical Education, to have defended her thesis "The residual effect of eccentric concentric prior exercise on aerobic capacity and muscle electrical activity during running of different intensity" (Biomedical Sciences, Biology) at the Lithuanian Academy of Physical Education on June 23, 2011.
Scientific advisor Prof. Dr. Arvydas Stasiulis.

Lietuvos kūno kultūros akademijos doktorantą **Laimutį Škiką**, 2011 m. birželio 30 d. Lietuvos kūno kultūros akademijoje apgynusį biomedicinos mokslų (biologijos) daktaro disertaciją tema „Achilo sausgyslės ir blauzdos raumenų morfologinių ir biomechaninių savybių įtaka pusiausvyros stabilumui".
Mokslinis vadovas prof. dr. Kazimieras Muckus.

We congratulate **Laimutis Škikas**, the student of doctoral studies at the Lithuanian Academy of Physical Education, to have defended his thesis "The influence of morphological and biomechanical properties of the Achilles tendon and calf muscles on balance stability" (Biomedical Sciences, Biology) at the Lithuanian Academy of Physical Education on June 30, 2011.
Scientific advisor Prof. Dr. Kazimieras Muckus.

ISSN 1392-5644