ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME
13

ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS
13

UNIVERSITY OF TARTU

ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME 13

TARTU 2008

Editor
Toivo Jürimäe
University of Tartu
18 Ülikooli Street
50090 Tartu
Estonia

This journal is indexed in: Sport Discus Database

Tartu University Press
www.tyk.ut.ee
Order No 536

CONTENTS

REARFOOT KINEMATICS IN DISTANCE RUNNERS: ASSOCIATION WITH OVERUSE INJURIES

H. Aibast[1], E. Pafumi[2], H. Gapeyeva[1], J. Ereline[1], A. Cicchella[2], M. Pääsuke[1]

[1] Institute of Exercise Biology and Physiotherapy, University of Tartu, Estonia,
[2] Faculty of Exercise and Sport Sciences, University of Bologna, Italy

ABSTRACT

Distance runners suffer often from overuse injures, caused by excessive pronation or supinating foot. The purpose of this study was to compare the rearfoot kinematics and the questionnaire results of incidences of overuse injuries symptoms. Fourteen distance runners, who were distributed into the more-symptomatic (MSL, n = 7) and less-symptomatic (LSL, n = 7) groups according to the questionnaire participated in this study. The subjects ran at average speed 3.79 $m \cdot s^{-1}$ on the 5,8 m runway with four markers set on rearfoot and shank, and kinematics were determined using the motion analysis system with 6 and 8 cameras. For the rearfoot kinematics analysis the angles between calcaneus and shank in both legs were measured: angle at impact; maximum angle; the pronation amplitude; time from impact to maximum angle; time from maximum angle to toe-off supination. The pronation amplitude in the right foot was greater ($p < 0.05$) in MSL compared to LSL group (5.5° and 8.2°, respectively; $p = 0.02$). The other measured parameters did not differ significantly between the groups. We concluded that the variations in rearfoot kinematics can not be the reasons for causing the symptoms of overuse and their origin should be searched from training errors.

Key words: rearfoot kinematics, running, overuse injures

INTRODUCTION

Running is one of the most popular forms of physical activity. Unfortunately the yearly incidence of injuries among runners is estimated to be between 37% and 56%, 70–80% of these injuries are of an overuse type and involve the knee, leg, ankle and foot [15]. Training errors are the predominant factor in producing runner's injuries, followed by anatomic factors, running shoes and surfaces. Anatomic factors generally involve abnormal biomechanics or malalignments of the lower extremities [6]. It has been affirmed that females are more predisposed for overuse injuries, but several research showing no differences between sexes [10, 8]. Runners with excessive or compensatory pronation of the foot are especially predisposed to injuries. Compensatory pronation with increased internal *tibia* rotation places additional stress upon the foot, ankle, knee, hip and lower back. More rigid foot represents a poor shock-absorbing mechanism due to inadequate foot flexibility to dissipate forces [14]. Supination and pronation are the movements of subtalar joint. With the help of rearfoot kinematics during running it is possible to indirectly calculate the movement of pronation/supination of the subtalar joint.

The human shank and foot complex is an intricate multi-joint mechanism fundamental for the interaction between lower limb and ground during locomotion. A most realistic relevant representation would involve a large number of anatomical landmarks, a robust and flexible technique for spatial registration together with a software tool for data organization [2]. There are many different methods and models for clinical and scientific use to measure foot kinematics [1, 18].

The aim of this study was to compare rearfoot movement during stance phase and the incidence of the symptoms of running-induced overuse injuries in the more-symptomatic (MSL) and less-symptomatic (LSL) subjects group. Therefore, we investigated with the four-marker indirect method [5, 7, 14, 16] the movement of the subtalar joint and tested the hypothesis that overpronative or too rigid foot can be the cause for more overuse injuries.

MATERIAL AND METHODS

Subjects

Fourteen distance runners (10 male and 4 female) around Bologna (Italy) participated in this study (trainings per week 6.9 ± 1.3 h; running kilometers per week 90 ± 40.2 km). The subjects were distributed into more-symptomatic (MSL) and less-symptomatic (LSL) groups by questionnaire. Their age and anthropometric characteristics are presented in Table 1. The subjects were screened by a questionnaire to determine their lower leg overuse injuries. The subjects who scored 21 or more of 33 were defined as MSL and those who scored 21 or less of 33 were defined as LSL. All the subjects were informed of the procedures to be utilized as well as the purpose of the study and their written informed consent for participation was obtained. Prior to testing, each subject read and signed an informed consent document approved by the University of Bologna.

Table 1. Age and anthropometric characteristics of the subjects (mean±SD)

		MSL (n=7)	LSL (n=7)
Age (years)		26.0±7.1	28.0±6.8
Height (cm)		173.0±8.0	169.9±11.9
Body mass (kg)		62.4±7.2	61.1±6.6
Body mass index (kg·m^{-2})		20.7±1.5	21.2±0.5
Trainings per week (h)		6.7±1.7	7.0±1.0
Running per week (km)		85.7±26.2	100.0±49.1
Knee circumference (cm)	**Left**	36.2±1.9	34.8±1.8
	Right	36.2±1.9	34.9±1.5
Ankle circumference (cm)	**Left**	25.0±1.7	24.3±1.5
	Right	25.2±1.4	24.4±1.4
Leg Lenght (cm)	**Left**	92.7±6.4	89.7±5.6
	Right	92.9±6.5	89.0±5.6

Notes: MSL – more symptomatic group (1 woman; 6 men); LSL – less symptomatic group (3 women; 4 men)

Assessment and Experimental protocol

The tests were carried out in the Movement Analysis Laboratory, Rizzoli Ortopaedic Institute, (Bologna, Italy) and in the Biomechanical Laboratory at the University of Bologna (Italy). The used equipment stereophotogrammetric system Vicon 612 (Vicon Motion Capture, Oxford UK) for human movement analysis with 8 television cameras M2 and 2 force plates (Kistler, Switzerland) at the frequency of registration 100 Hz, at Rizzoli Institute and Vicon 360 with 6 television cameras, 200 Hz in the Biomechanical Laboratory at the University of Bologna. Four spherical markers of 9-mm diameter were used: (1) the most prominent posterior part of *calcaneus*; (2) 3 cm upward from the first; (3) 8 cm upward from the second; (4) 8 cm upward from the third. The cameras were positioned to obtain a rear (frontal plan) view of the shank and *calcaneus* during the stance period. The subjects were running on the 5.8 m runway with the average speed of 3.79 m/s. A force platform was embedded in the middle of the runway, where the subjects had to step six times with the left and six times with the right leg. The data was calculated using Vicon Workstation Ver. 4.1. The angle between rearfoot and shank was found on the graph and subtracted from 180°.

During the anthropometrical measurements, the subjects lay on the therapeutic table. The circumferences of the knee, ankle and the length of the leg from *spina iliaca anterior posterior* to medial malleolus were measured. Four markers were fastened on the *calcaneus* and shank when the subject was standing on the platform with feet apart 10 cm. Before the experimental procedure, the subjects were acquainted with the laboratory and the 10-m running track, which included 5.8 m runway with a force platform. They performed barefoot running trials to determine their starting positions, self-selected speed and their preferred cadence. They were instructed to step on the force platform by left or right leg, six times each. The ground reaction force and shank and *calcaneus* kinematics data were collected during 12 running trials.

From the coordinates the following angles were calculated (Figure 1): (1) impact angle; (2) maximal rearfoot angle; (3) pronation amplitude; (4) the time from impact to maximum pronation; (5) the duration of pronation.

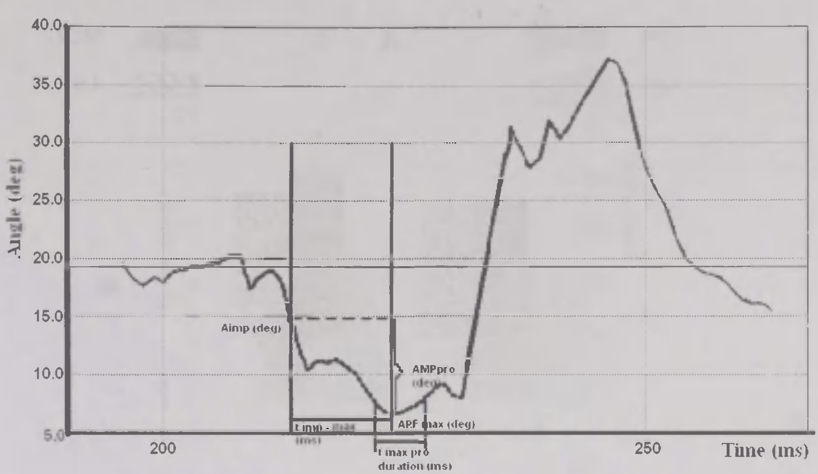


Figure 1. Representative rearfoot angle versus time curve for stance phase. Aimp – impact rearfoot angle; t imp – max – time from impact to maximum rearfoot angle; t max pro duration – duration of the maximum pronation; ARF max – maximum rearfoot angle; AMPpro – amplitude of pronation.

Statistical analysis

Date are expressed as means and standard deviation (±SD). An one-factor ANOVA with the Tukey post-hoc test was used to compare anthropometric parameters between groups. A level of $p < 0.05$ indicated statistical significance.

RESULTS

The rearfoot impact angle and the maximum angle did not differ between the two measured groups (Fig. 2). The amplitude of right foot pronation was greater ($p < 0.05$) in LSL than MSL group (8.2° and 5.5° respectively, $p \leq 0.02$). There were no significant differences in the pronation amplitude of the left foot between the groups (Fig. 2).

The time parameters (the time from impact to maximum pronation and the duration of maximal pronation) did not show any significant differences between two groups (Fig. 3).

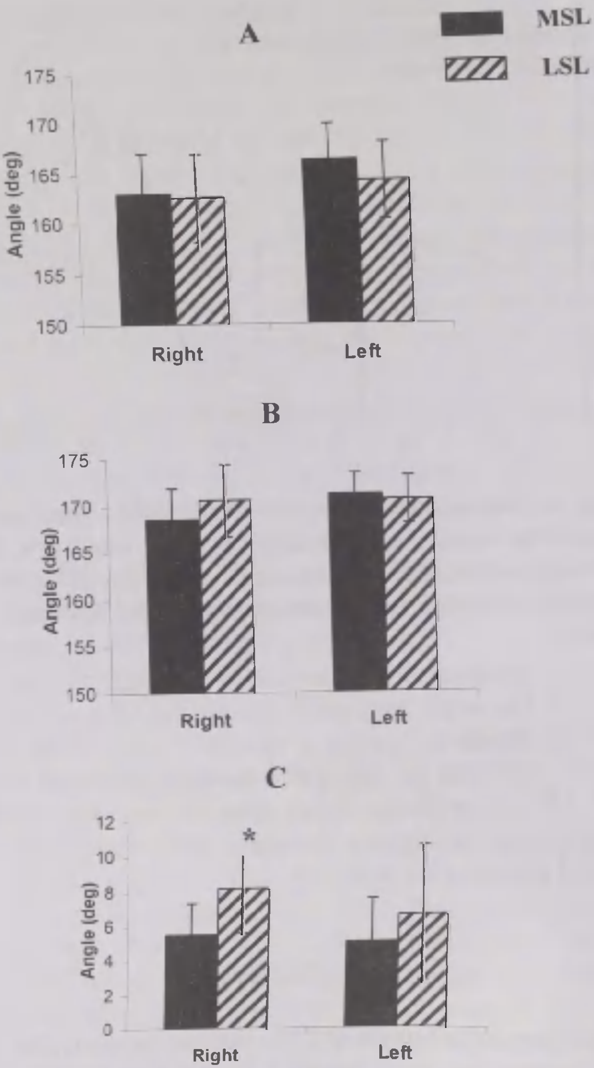


Figure 2. The angle between the shank and rearfoot in impact (A), the maximum angle between the shank and rearfoot (B) and the amplitude of pronation (C) in the right and left foot more (MSL) and less (LSL) symptomatic groups (mean±SD).* $p \leq 0.05$.

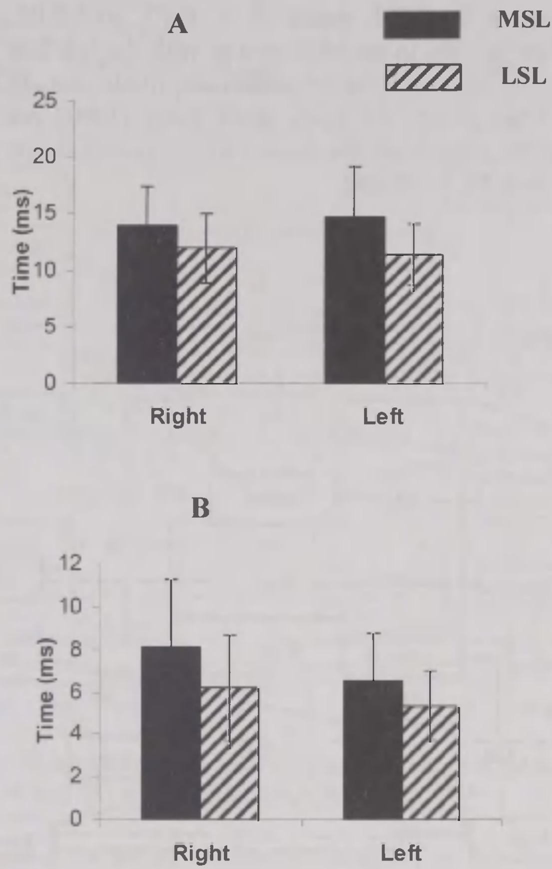
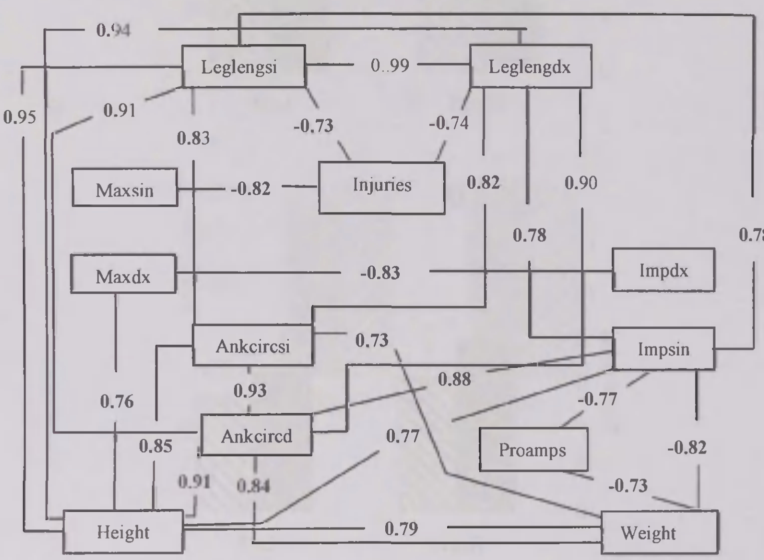


Figure 3. The time from impact angle to maximal pronation (A) and the duration of maximal pronation (B) in the right and left foot more (MSL) and less (LSL) symptomatic groups (mean±SD).

Figure 4 demonstrates significant correlations between the measured characteristics in MSL group A and LSL group B. In the MSL group, the injuries correlated negatively with the length of the right ($r = -0.74$; $p < 0.05$) and left leg ($r = -0.73$; $p < 0.05$) and with the maximal rearfoot angle in the left foot ($r = -0.82$; $p < 0.05$). Also the impact angle in the left foot correlated negatively with the amplitude of pronation in the MSL group ($r = -0.77$; $p < 0.05$). The weight correlated negatively in the MSL group with the left foot impact angle ($r = -0.82$; $p < 0.05$) and the pronation amplitude ($r = -0.73$; $p < 0.05$).

In the LSL group, the body mass index (BMI) correlated negatively with the time from the impact to the maximum pronation in the left leg ($r = -0.74$; $p < 0.05$).

A



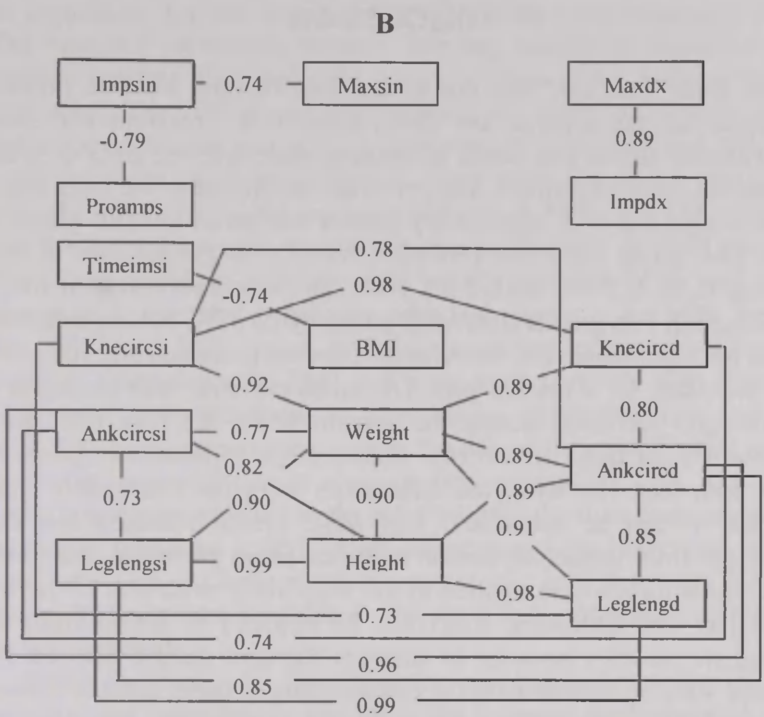


Figure 4. Significant correlation coefficients between the mean variables in more (A) and less (B) sympomatic groups.

Leglengsi – lenght of the left leg; Leglengdx – lenght of the right leg; Maxsin – the maximal left shank-rearfoot angle; Maxdx – the maximal right shank-rearfoot angle; Impdx – right shank-rearfoot angle at impact; Impsin – left shank-rearfoot angle at impact; Ankcircsi – left ankle circumferance; Ankcircd – right ankle circumferance; Proamps – the left pronation amplitude; Timeimsin – the time from left leg impact to the maximum pronation; Knecircsi – the circumference of left knee; Knecircd – the circumference of right knee; BMI – body mass index.

DISCUSSION

This study indicated that during barefoot running with no previous fatigue did not emerge any differences in the rearfoot and shank movement angles that could be causing more overuse injuries symptoms for distance runners. The pronation amplitude in the right foot in the LSL group was significantly greater compared to MSL group. In the LSL group right foot pronation was 32.7% greater than in MSL group (LSL 8.2° vs. MSL 5.5°). Also the pronation in the left foot in LSL group was greater than MSL group by 23.65%, but the difference was not significant. The interchange between pronation and supination is necessary for a normal gait. The problems arise with excessive or prolonged pronation during the support phase [6]. The LSL group showed even faster times from impact angle to maximum pronation for both feet. However, the differences were not statistically significant. It can be speculated that MSL group indicated too slow changes from impact supination to stance phase pronation, due to this increased forces were applied to the supporting structures of the foot and leg. The additional effort will be required of the intrinsic and extrinsic muscles in order to stabilize the foot during push-off [6]. There were no indicators in the current study to prove that the subjects in the MSL group suffer more with right side injuries. However, the results agree with other studies [5]. The time parameters were equally shorter in the LSL compared to MSL group and the differences between the right and the left leg were not significant. The differences were symmetrical.

The tendency for a runner to become injured on a particular side may be related to lower extremity asymmetry [17]. In the present study, we did not find any statistically significant differences either in ankle and knee circumferences or the length of the legs between two groups. It is interesting to note that the overuse injuries symptoms were negatively correlated only in the MSL group with the length of both legs and the maximum pronation angle in the left leg. The leg length can change the location of the center of gravity. Perttunen et al. [12] found in their study during walking that the shorter limb bore the weight for less time than the longer limb and the pressure was higher in the push-off phase on the longer limb. It is important to notice that the differences increased at faster walking and would probably increase even more with running. The hypothesis can be made that during the running with increasing speed even the smallest differences could be significant for the development of injuries over prolonged time. The negative correlation between left leg maximum pronation and injuries indicate that the rigid supinated foot more overuse injury symptoms. The MSL group showed positive correlation between right ankle circumference and left leg impact angle. It can indicate that the right leg could be more dominant. Body mass correlated positively with the left and right ankle circumferences in MSL and LSL groups, but the correlation was greater on the right ankle in both groups. Pronation amplitude differed significantly between MSL and LSL groups and correlated negatively with body mass in the MSL group. The increased body mass probably requires greater pronation to cushion. But neither the BMI nor body mass correlate with injuries. This result is controversial to other study, where the BMI was the most significant parameter to cause the risk of the medial tibial stress syndrome, one of the most common overuse injuries [13]. The BMI had a negative correlation in the left foot with the time from impact to maximum pronation in LSL group. Interestingly, the body mass correlated only with the anthropometric parameters in LSL group. In MSL group the body mass correlated with the left leg pronation amplitude and impact angle.

Davis and Dierks [3] found that the coupling between the rearfoot eversion and knee flexion did not differ between patellofemoral pain syndrome group and the controls, but both groups increased their coupling angles over the course of the prolonged run. There are more evidences that indicate the influence of fatigue to the appearance of overuse injures [9]. It seems that the fatigue and, as mentioned earlier, training errors are the first origin for overuse injures [11]. It seems that the 90-min running was not enough for exhausting [4], but the accumulation of impact loading overtime [6, 5]. We can conclude that decreased pronation amplitude can be the cause for higher in incidence of the overuse injuries symptoms in MSL compared to LSL group. However, due to major differences between the research results, it is still more likely that training errors and the non-individual approach to the runner during the training planning process cause more risk for overuse injuries.

REFERENCES

1. Benedetti M. G., Leardini A., Bianchi L., Berti L., Giannini S. (2008) Comparison of outputs of different models for foot kinematics. Proceedings of 1st Foot and Ankle Biomechanics Community Congress. Bologna, September 4–6, 2008, 91.
2. Biagi F., Berti L., Benedetti M. G., Leardini A. (2008) Skeletal-based animation in multi-segment foot kinematics. Proceedings of 1st Foot and Ankle Biomechanics Community Congress. Bologna, September 4–6, 2008, 90.
3. Davis I. S. and Dierks T. A. (2008) Rearfoot and knee coupling over a prolonged run in runners with patellofemoral pain syndrome. Proceedings of 1st Foot and Ankle Biomechanics Community Congress. Bologna, September 4–6, 2008, 44.
4. Deleu P.-A., Matricali G., Leemrijse T., Deschamps K. (2008) Impact of 90 minutes running exercise on plantar loading of the forefoot: a prospective study on symptom-free athletes. Proceedings of 1st Foot and Ankle Biomechanics Community Congress. Bologna, September 4–6, 2008, 47.
5. Hreljac A., Marshall N. R., Hume A. P. (2000) Evaluation of lower extremity overuse injury potential in runners. Med. Sci. Sports Exerc. 32: 1635–1641.
6. James S. L., Jones D. C. (1990) Biomechanical aspects of distance running injuries. In: Biomechanics of Distance Running, P. R. Cavanagh (ed) Illinois: Human Kinetics, 249–269.
7. Johanson A. M., Donatell R., Wooden M. J., Andrews P. D., Cummings G. S. (1994) Effects of three different posting methods on controlling abnormal subtalar pronation. J. Phys. Ther. 74: 149–161.
8. Milliron M. J., Cavanagh P. R. (1990) Sagittal plane kinematics of the lower extremity during distance running. In: Biomechanics of Distance Running, P. R. Cavanagh (ed) Illinois: Human Kinetics, 65–105.
9. Nagel A., Fernholz F., Kibele C., Rosenbaum D. (2008) Long distance running increases plantar pressures beneath the metatarsal heads. A barefoot walking investigation of 200 marathon runners. Gait Posture. 27: 152–155.
10. Nguyen A.-D., Shultz S. J. (2007) Sex differences in clinical measures of lower extremity alignment. J. Orthop. Sports Phys. Ther. 37: 389–398.
11. Olesen C. O., Nielsen R. G., Rathleff M., Simonsen O., Moelgaard C., Jensen K., Lundbye-Christensen S., Kaalund S. (2008) Does exces-

sive pronation cause pain? Proceedings of 1st i-FAB Congress. Bologna, September 4–6, 2008, 79.
12. Perttunen J. R., Anttila E., Södergård J., Merikanto J., Komi P. V. (2004) Gait asymmetry in patients with limb length discrepancy. Scand. J. Med. Sci. Sports. 14: 49–56.
13. Plisky M. S., Rauh M. ., Heiderscheit B., Underwood F. B., Tank R. T. (2007) Medial tibial stress syndrome in high school cross-country runners: Incidence and Risk Factors. J. Orthop. Sports Phys. Ther. 37: 40–47.
14. Stergiou N., Bates B. T., James L. S. (1999) Asynchrony between subtalar and knee joint function during running. Med. Sci. Sports Exerc. 31: 1645–1655.
15. Stergiou N., Bates B. T., Kurz M. J. (2003) Subtalar and knee joint interaction during running at various stride lengths. J. Sports Med. Phys. Fitness. 43: 319–326.
16. Tsai L.-C., Yu B., Mercer V. S., Gross T. M. (2006) Comparison of different structural foot types for measure of standing postural control. J. Ortop. Sports Phys. Ther. 36: 942–953.
17. Zifchock A. R., Davis I., Hamill J. (2006) Kinetic asymmetry in female runners with and without retrospective tibial stress fractures. J. Biomech. 39: 2792–2797.

Wolf S. (2008) Foot motion in children and adults. Proceedings of 1st Foot and Ankle Biomechanics Community Congress. Bologna, September 4–6, 2008, 83.

Correspondence to:
Herje Aibast,
Institute of Exercise Biology and Physiotherapy
University of Tartu
Jakobi 5, Tartu 51014
Estonia

CHANGES IN TECHNIQUE OF HANDSPRING DOUBLE SALTO FORWARD TUCKED PERFORMED ON HORSE AND VAULTING TABLE

I. Čuk, S. M. Ferkolj

University of Ljubljana, Faculty of Sport, Ljubljana, Slovenia

ABSTRACT

Aim of the research was to determine changes in technique parameters while performing handspring double salto forward tucked (Roche) on old horse and new vaulting table. On a sample of 9 vaults performed in 2000 World Cup in Ljubljana on horse and 9 vaults performed at World championship in Debrecen on vaulting table we made a series of t-tests for biomechanics kinematics parameters. There are differences in many variables, but most important are those related to the support phase (position of hands, take off vertical velocity) which also causes better outcome during the flight and landing. New vaulting table is really much better apparatus than the horse as has better place for support, which makes easier production of angular momentum (inclined table) and higher vertical take off velocity.

Key words: artistic gymnastics, vault, horse, table, biomechanics, double salto

INTRODUCTION

At World Championship 2001 in Ghent FIG (FIG, 2001) changed their tradition and they replaced old horse with vaulting table (Figure 1). After pre tensioned apparatus in '50 this is the biggest change in apparatus design.

By FIG norms vaulting horse is 160 cm long, 35 cm wide and 135 high (FIG, 1989). Vaulting table is 95 cm wide and 95 to 105 cm long and 135 cm high. Wider and shorter table is safer [4]. Upper area of the table is slightly inclined (5 degrees). New apparatus has more advantages with wider and slightly inclined support area, what gives gymnast better anatomical support, and better position for arms take off action (Figure 2) [1, 4].

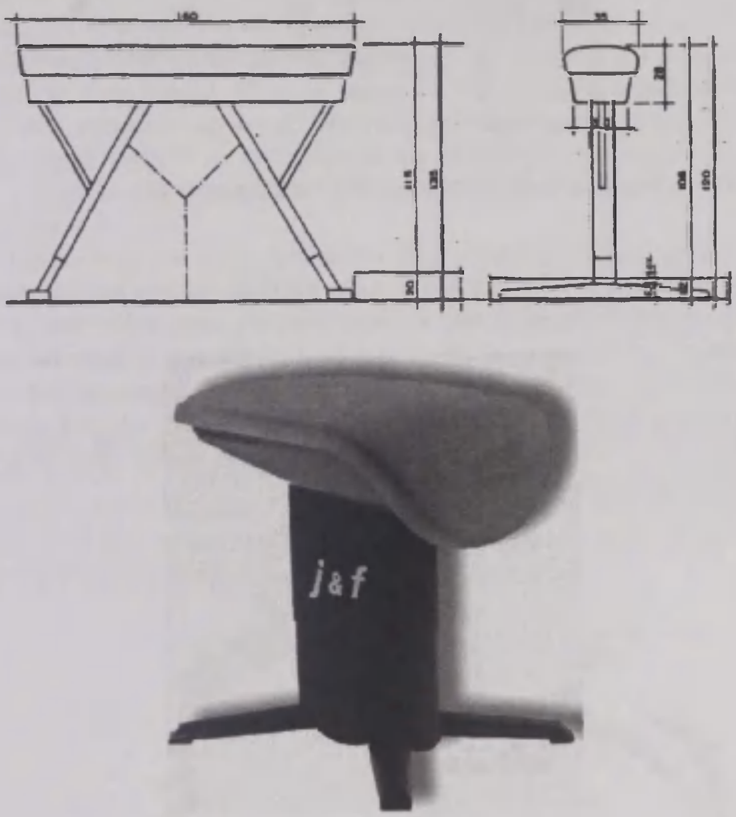


Figure 1. Vaulting horse and vaulting table (FIG, 1989) [2]

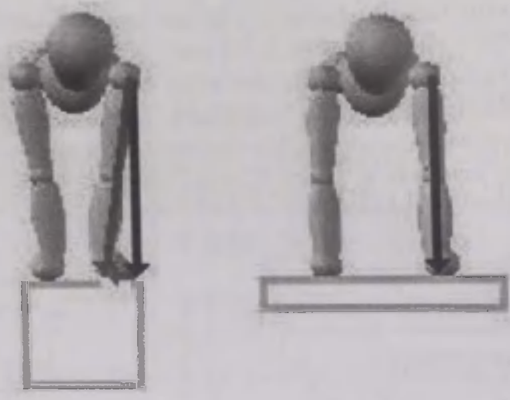


Figure 2. Support position on horse and vaulting table [1]

As we were aware that support is more efficient on new vaulting table, we were searching if beside support are also some other changes in technique of top level vaults and how this change reflects on other biomechanics variables. One of the most difficult jumps nowadays is handspring double salto forward tucked (FIG, 2006), which gymnasts performed on old horse and new vaulting table, within such quantity that we can do statistical analysis.

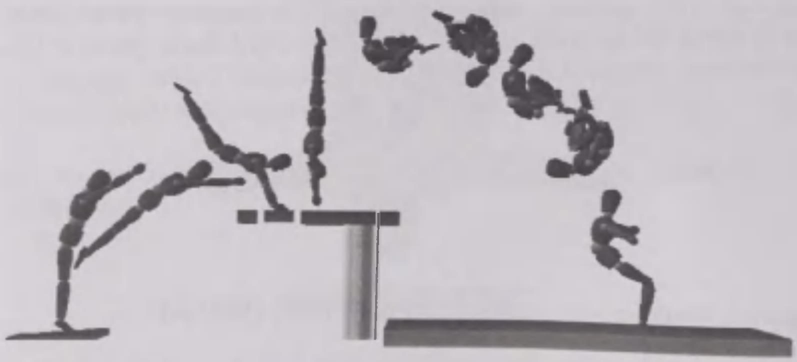


Figure 3. Handspring double salto forward tucked (Roche) [1]

MATERIALS AND METHODS

Sample of gymnasts were those gymnasts who have performed handspring and double salto forward tucked at World Cup competition in Ljubljana 2000 (N = 9) and those gymnasts who have performed same type of vault at World Championship in Debrecen 2002 (N = 9).

Kinematic analysis were done with APAS-Ariel performance analyses system (Ariel Dynamics Inc., San Diego, CA). We used Sušanka, Otahal, Karas [8] 15-segment body model defined with 17 points. All the jumps were recorded during the competition with two orthogonal SVHS cameras with 50 frames per second. All data were smoothed with digital filter of range 7. We calculated trajectories, velocities, time and angles of important positions in following phases of the vault: support on springboard, the first flight, support on apparatus, the second flight and landing; all together we defined 104 variables.

Statistic analysis were done with SPSS (Statistical Package for the Social Sciences, 12.0, Chicago, IL, USA). First we calculated differencies in quality of jumps between horse and table. Good jump meant jump without fall (on table were 6 and on horse 5 good ones) and bad jump was defined as jump with fall (on table were 3 and on horse 4 bad ones). Calculated χ^2 (0,12; non significant differences) showed no differences in quality of jumps. For each variable we calculated descriptive statistics, than F-test between both groups and considering results of F-test we calculated t-test (for equal or unequal variances), only significant differencies in variables are introduced.

RESULTS AND DISCUSSION

Table 1. Results of springboard support phase variables

		Table	Horse	p(F)	pt-test
velocity BCG Vx 1. touch springboard *[m/s]*	**X**	**7.967**	**7.581**	0.562	**0.010**
	MAX	8.350	7.875		
	MIN	7.575	7.150		
	SD	0.283	0.229		
	SE	0.188	0.169		
velocity BCG Vy 1. touch springboard *[m/s]*	**X**	**1.113**	**0.784**	0.674	**0.038**
	MAX	1.350	1.025		
	MIN	0.725	0.450		
	SD	0.236	0.200		
	SE	0.172	0.158		
velocity BCG Vxyz 1. touch springboard *[m/s]*	**X**	**8.049**	**7.623**	0.531	**0.008**
	MAX	8.459	7.932		
	MIN	7.624	7.198		
	SD	0.298	0.237		
	SE	0.193	0.172		
velocity BCG Vx last touch springboard *[m/s]*	**X**	**5.042**	**4.667**	0.739	0.062
	MAX	5.625	5.350		
	MIN	4.525	4.250		
	SD	0.328	0.370		
	SE	0.202	0.215		
velocity BCG Vy last touch springboard *[m/s]*	**X**	**4.654**	**4.597**	0.368	0.945
	MAX	4.725	4.925		
	MIN	4.300	4.200		
	SD	0.138	0.192		
	SE	0.131	0.155		
velocity BCG Vxyz last touch springboard *[m/s]*	**X**	**6.868**	**6.562**	0.433	**0.031**
	MAX	7.346	6.875		
	MIN	6.475	6.351		
	SD	0.244	0.183		
	SE	0.175	0.151		
angle thrunk / thig hip *[degrees]*	**X**	**103.0**	**111.9**	0.910	**0.005**
	MAX	111.9	118.3		
	MIN	92.6	101.4		
	SD	5.9	5.7		
	SE	0.9	0.8		

Velocity (in xyz) of gymnasts BCG (Body Centre of Gravity) at touch down on springboard jumping on horse is 7.623 m/s and 8.049 m/s on table, the difference of 0.426 m/s is significant Velocity (in xyz) of gymnasts BCG at take off from the springboard jumping on horse is 6.562 m/s and 6.868 m/s on table, lose of velocity is for both similar (horse 1.162 m/s and table 1.172 m/s). At touch down BCG velocity in x and y axis is higher for table and also hip angle show more open gymnast position, while at take off persist only the differnce in BCG velocity (in xyz). Diferences in velocities in x and y axis are not significant, what shows quite an interesting variance, how gymnasts gain angular momentum on very individual basis. Higher BCG velocity on springboard at touh down and take off table can be explained by famous Fitts law [3, 7], which says bigger the area to reach higher velocity can be used; higher velocity means lower control and lover precision. As the horse has smaller support area than table [1, 4, 5, 6] handspring double salto forward tucked is performed with lower BCG velocity on the horse according to Fitts law.

Table 2. Results of support phase variables

		Table	**Horse**	p(F)	pt-test
Support time	**X**	**0.162**	**0.162**	0.078	1.000
	MAX	0.180	0.200		
	MIN	0.140	0.140		
	SD	0.012	0.023		
[s]	**SE**	0.039	0.054		
Hand grip	**X**	**0.439**	**0.176**	0.012	0.000
	MAX	0.490	0.213		
	MIN	0.325	0.149		
	SD	0.054	0.020		
[m]	**SE**	0.082	0.050		
Proportion Shoulders wide/ Support wide	**X**	**0.992**	**2.494**	0.179	0.000
	MAX	1.314	2.822		
	MIN	0.859	2.127		
	SD	0.143	0.236		
[m]	**SE**	0.134	0.172		

		Table	**Horse**	p(F)	pt-test
Velocity	**X**	**3.929**	**3.644**	0.915	0.379
BCG	**MAX**	4.675	4.375		
Vx	**MIN**	3.225	3.200		
Take off	**SD**	0.438	0.421		
[m/s]	**SE**	0.234	0.229		
Velocity	**X**	**4.146**	**3.803**	0.601	**0.005**
BCG	**MAX**	4.425	4.125		
Vy	**MIN**	3.900	3.500		
Take off	**SD**	0.183	0.222		
[m/s]	**SE**	0.151	0.167		
Velocity	**X**	**5.724**	**5.278**	0.492	**0.037**
BCG	**MAX**	6.235	5.819		
Vxyz	**MIN**	5.257	4.743		
Take off	**SD**	0.286	0.368		
[m/s]	**SE**	0.189	0.214		

On the table gymnast has arms almost parallel and orthogonal to support, what is most efficient kind of support. Proportion between shoulders and hand support changed as we expected [1, 4]. Better position of arms gives them position to generate higher take off force what shows out also as higher BCG velocity in y axis. By calculating difference of force between vertical component and horizontal compomponent; vertical component of force on table is 3% higher. Inclined table (5%) rises orthogonal force on table, what gives by reaction force of table better take off results (higher take off force, higher angular momentum [5].

Results of support phase show that support time remained almost identical on vaulting table, therefore it can be considered, as elasticity of new vaulting table was not changed, that 0.162 second is somewhat ideal time for force impact [1].

Significant difference is between velocity at take off from apparatus. Higher vertical velocity is on table, as well as velocity in space. Similar results has found BY Takei [9]. Angles between body segments (head, arms, trunk, legs) has not changed significantly.

Table 3. Results of flight phase variables

		Table	Horse	p(F)	pt-test
Angular velocity	**X**	**800.5**	**800.2**	0.332	0.318
From take off	**MAX**	822.9	830.0		
To	**MIN**	728.0	767.4		
1st salto	**SD**	29.5	20.7		
[degrees./s]	**SE**	1.9	1.6		
Angular velocity	**X**	**1104.5**	**1075.2**	0.584	0.972
1st salto	**MAX**	1200.0	1125.0		
to	**MIN**	1000.0	1000.0		
2nd salto	**SD**	64.1	52.5		
[degrees./s]	**SE**	2.8	2.6		
Angular velocity	**X**	**693.2**	**797.7**	0.412	**0.032**
2nd salto	**MAX**	820.9	960.5		
to	**MIN**	605.0	606.0		
Touch down	**SD**	86.0	116.2		
[degrees./s]	**SE**	3.3	3.8		
Time	**X**	**1.056**	**1.022**	0.503	**0.021**
Of	**MAX**	1.080	1.060		
flight	**MIN**	1.000	0.980		
	SD	0.024	0.031		
[s]	**SE**	0.055	0.062		
Time	**X**	**0.230**	**0.258**	0.010	**0.027**
from take off	**MAX**	0.240	0.320		
to max	**MIN**	0.220	0.220		
contraction	**SD**	0.011	0.029		
[s]	**SE**	0.036	0.060		
Time	**X**	**0.247**	**0.209**	0.055	**0.005**
from 2nd salto	**MAX**	0.260	0.220		
to	**MIN**	0.200	0.200		
touch down	**SD**	0.022	0.011		
[s]	**SE**	0.052	0.036		
Angle	**X**	**49.3**	**42.5**	0.864	**0.023**
trunk	**MAX**	57.6	53.1		
Thigh	**MIN**	42.5	33.2		
Max.	**SD**	5.9	5.5		
[degrees]	**SE**	0.9	0.8		

		Table	Horse	p(F)	pt-test
Angle	**X**	**60.4**	**49.3**	0.437	**0.001**
Thigh	**MAX**	69.2	58.3		
Calf	**MIN**	54.1	40.4		
Max.	**SD**	4.8	6.3		
[degrees]	**SE**	0.8	0.9		

Higher vertical take off force on table is reason for higher peak BCG height in the second flight, higher is BCG after finishing the first and the second salto on table. In a whole the time for the second flight is on table longer.

On the table is also faster bending from the take off up to the maximum tuck position in salto. Reason is because angles on horse are smaller, therefore gymnast on table is more open (moment of inertia is higher). Similar results were obtained also by Takei [9].

Surprisingly angular velocity during first and second salto is for both same, however hip and knee angles during salto are significantly different, as during vaults from vaulting table gymnasts are more open, what means, that during flight phase they have higher angular momentum [5, 10].

On table is extended time from finished second salto to the first contact at landing, as BCG height after the second salto on horse is 2.07 m and on table 2.29 m. With higher BCG position and with stretching prior the landing gymnast on table lowers angular velocity what gives him better chances to control landing.

Hip and knee angles at the moment of first touch down are higher on table (gymnasts is more open). Also on table BCG is in moment of touch down higher for 0.12 m.

New vaulting table allows gymnast to gain higher runway velocity, better anatomic-functional position of arms, and therefore higher vertical velocity from apparatus and angular momentum (inclined table), what results in longer time of flight, higher amplituded of flight and better position to prepare for landing [1, 5].

Table 4. Results of landing variables

		Table	Horse	p(F)	pt-test
Angle	**X**	**137.7**	**106.6**	0.731	**0.006**
Trunk	**MAX**	165.0	147.1		
Thigh	**MIN**	98.5	85.2		
Touch down	**SD**	22.2	19.6		
[degrees]	**SE**	1.7	1.6		
Angle	**X**	**133.0**	**108.7**	0.441	**0.009**
Thigh	**MAX**	152.4	135.9		
Calf	**MIN**	94.1	88.8		
Touch down	**SD**	19.6	14.8		
[degrees]	**SE**	1.6	1.4		

From our results we can conclude that new vaulting table significantly changed performances of gymnasts. However there might be also a catch. Our investigation was performed in time, where there was not a lot gymnast who can perform such vault and accommodation to the new vaulting table was not so world wide spread, and only best gymnasts were performing handspring double salto forward tucked. As gymnast easier gains during the support higher angular momentum, this can be dangerous for those gymnasts who are not physically, technically and mentally prepared for such a difficult vault as new vaulting table gives them blind self confidence.

REFERENCES

1. Čuk I., Karacsony I. (2004) Vault: methods, ideas, curiosities, history. Ljubljana, ŠTD Sangvinčki.
2. Jenssen & Fritsen (2003) The vault of the next generation. Netherlands. www.gymmedia.com/jenssen-fritsen/.
3. Magill R. A. (1998) Motor learning – Concepts and Applications. Louisiana, WCB McGraw-Hill, 5th edition.
4. McNeal J. R. (2003) Some guidelines on the transition from the old horse to the new table. USA, Esteren Washington University.
5. Prassas S. (2002) Vaulting mechanics. USA, Colorado State University.

6. Rand T. (2003) New vaulting table. USA Gymnastics. (www.usa-gymnastics.org)
7. Schmidt R. A. (1999) Motor control and learning: A behavioral emphasis. Failure analysis associates, Inc. And University of California, Los Angeles.
8. Sušanka P., Otahal S. Karas V. (1987) Zaklady biomechanicky telesnyh cvičeni. Praha, Universita Karlova.
9. Takei Y. (2007) The Roche vault performed by elite gymnasts: Somersaulting technique, deterministic model and judges scores. J. Appl. Biomech. 23, 1–11.
10. Winter A. D. (1990) Biomechanics and motor control of human movement. Waterloo, University of Waterloo.

ACKNOWLEDGEMENTS

We would like to thanks Ministry of Higher Education and Science for supporting program Kinesiology of monostructural, polystructural complex and conventional sports. Thanks also to International Gymnastics Federation, Hungarian Gymnastics Federation and Slovenian Gymnastics Federation for allowing us to do experiment during competitions.

Corresponding author:
Ivan Čuk
University of Ljubljana
Faculty of Sport
Gortanova 22
1000 Ljubljana
Slovenia

CHARACTERIZATION OF THE PROLACTIN RESPONSE TO PROLONGED ENDURANCE EXERCISE

A. C. Hackney
Endocrine Section – Applied Physiology Laboratory
University of North Carolina
Chapel Hill, North Carolina, USA

ABSTRACT

This study characterized the blood prolactin responses to a prolonged endurance exercise bout in comparison to a resting, control period with no exercise. Six healthy exercise trained males completed both a 90 minute cycle exercise (70% VO_{2max}) and a rest-control experimental session under standardized conditions. Blood samples were collected at – 15, 0 (exercise start), 15, 30, 45, 60, 75, 90 (exercise end), 105, and 120 minute time points in the exercise and rest-control sessions. Prolactin concentrations were analyzed using radioimmunoassay procedures and tested for significant changes with ANOVA analysis. In the exercise session, prolactin concentrations from 45 to 120 minutes were significantly greater than the 15 minute concentration before exercise ($p < 0.01$). Furthermore, the exercise concentrations at 45 to 120 minutes were also significantly greater than the concentrations observed at the comparable rest-control time points ($p < 0.01$; approximately 300% elevation). The frequent blood sampling protocol used in this study clearly portrays the magnitude, timeline, and extend of the prolactin response to prolonged endurance activity. The mechanism and role for the prolactin response was not the focus of this study, but relative to the latter, it is speculated the hormonal change could pertain to signaling energy usage-status within the body and, or prompting immune system activation.

Key words: hormones, stress, endocrine, methodology

INTRODUCTION

Prolactin is a hormone released primarily by the anterior pituitary in humans [1]. Across several species its release and physiological function has been linked to stress reactivity, water balance, immune system activation and reproductive function [1, 2, 4, 7, 12]. A vast majority of the research on prolactin relates to this last topic due to the fact that prolactin has long been associated with lactation in women [1] and in excessive quantities to gonadal suppression in both men and women [1, 13].

Copious research indicates physical exercise (e.g., sports training and competitions) results in a significant and substantial increase in the circulating levels of prolactin [3, 5, 8, 9]. However, there appears to be a major methodological limitation in much of the available research on prolactin and exercise. Specifically, many exercise studies have typically looked at prolactin responses to exercise with too infrequent of blood sampling protocols and, or without a non-exercise control assessment of the hormone [e.g., 3, 8]. Regrettably, these methodological constraints have compromised the validity of exercise studies attempting to determine and quantify the prolactin response to specific exercise sessions.

For the above reasons, the present study was undertaken, the purpose being to characterize the prolactin responses to an exercise bout in comparison to a rest-control period with no exercise. In this study a 90 minute intensive exercise bout (70% maximal oxygen uptake [VO_{2max}]) was utilized due to previous research demonstrating this would result in substantial prolactin responses [5, 8].

METHODS AND PROCEDURES

The subjects for this study were six healthy male endurance athletes who had been involved with exercise training for > 5 years. Each subject gave written informed consent and all research procedures were reviewed and approved by university ethical and human research safety committees.

Subjects reported to the laboratory on two occasions: (1) a rest-control session and, (2) an exercise session. The time of day for each experimental session was standardized and controlled. The order of session administration was randomized and in each situation subjects were asked to report 8 hours post-prandial, having refrained from physical activity (24 hours before) and to have avoided excessive stressful personal situations or events. Furthermore, the ambient environment conditions were replicated in the exercise and rest-control sessions and where thermally neutral (20–25°C, low relative humidity) as excessive heat exposure promotes prolactin release [8].

Aspects of the exercise protocols to determine the subjects VO_{2max} and the submaximal exercise protocols have been reported elsewhere [3, 5]. However, briefly the subjects completed a graded incremental cycle exercise test (3 minute stages, 50 W workload increases, continuous respiratory gas analysis) to exhaustion to determine their VO_{2max}. These results were used to calculate the submaximal workload to elicit ~70% of VO_{2max} for their 90 minute cycle exercise session. The exercise and, or rest-session occurred within 2 weeks of the completion of the VO_{2max} testing. All exercise was preformed on a mechanically braked cycle ergometer (Monark, Sweden) and at 15 minute intervals throughout the exercise VO_2 (i.e., respiratory gases; Rayfield, USA), heart rate, and rating of perceived exertion were monitored.

Prior to each experimental session an anticubital venous catheter was inserted into the non-dominant arm of the subjects, and they were allowed to rest quietly for 15 minutes in a supine position. Approximately 15 minutes (–15 min.) before beginning the 90 minutes submaximal exercise or rest-control session the first blood specimen (3 mL) was withdrawn. Then at 15 minute intervals afterwards specimens were withdrawn at; 0, 15, 30, 45, 60, 75, 90, 105, and 120 minutes (exercise was 0 to 90 minute). In the rest-control session the subjects sat upright and read or watch television. During both sessions the subjects consumed water *ad libitum*.

Blood specimens were collected into EDTA treated tubes and placed immediately on ice until preparation for storage. Blood collection tubes were later centrifuged at 3000 x g for 15 minutes at 4°C to separate plasma. For each tube the separated plasma was aliquoted into cyro-freeze tubes and stored at –80°C until hormonal analysis could be completed. Plasma was analyzed in duplicate for prolactin concentration using commercial radioimmunoassay procedures (DPC Inc., USA). Assay sensitivity was ~0.4 μg/L and all within and between coefficients of variation for the assays were less than 10%.

Statistical analyses were performed with the "Statistica" software package (version 6.0, USA). Data are reported as means plus or minus the standard error of the mean. Repeated measures analysis of variance was used to assess the hormonal concentrations for mean differences, with subsequent post hoc analysis being the Fisher *lsd* procedure. Statistical significance was set at $p \leq 0.05$.

RESULTS

The physical characteristics of the subjects were as follows: age = 23.5 ± 2.0 yr, height = 179.5 ± 2.5 cm and body mass = 76.0 ± 1.9 kg. The VO_{2max} of the subjects was 60.3 ± 3.9 mL/kg/min.

All subjects completed the 90 minute submaximal exercise session with no major difficulties. They displayed normal and expected steady-state cardiovascular responses for such demanding exercise (data not shown). There was a tendency in some subjects to display a slight degree of cardiac drift by the end of the exercise, however, profuse fluid intake minimize the magnitude of this phenomenon.

The prolactin concentrations during each of experimental sessions are displayed in Figure 1. During the rest-control session the prolactin concentrations varied over the blood sampling times, but no significant differences were noted. Conversely during the exercise session significant increases in prolactin were detected. The exercise session concentrations from minute 45 to 120 were significantly greater than the –15 minute concentration before exercise ($p < 0.01$). Furthermore, the exercise session concentrations at 45 to 120 minutes were also significantly greater than the concentrations observed at the comparable rest-control time points ($p < 0.01$).

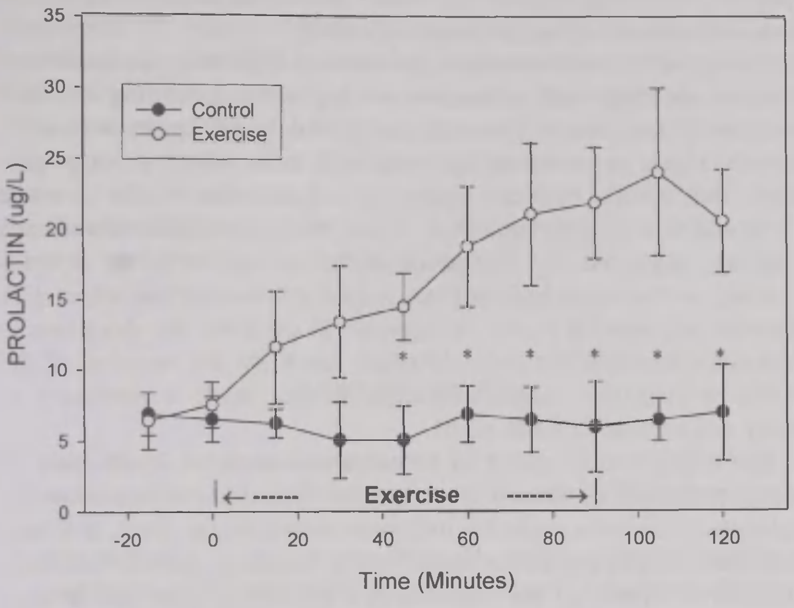


Figure 1. Prolactin concentrations in a resting, control session (filled circles) and a exercise session (open circles; 90 minutes duration, 70% VO_{2max}). All values are means ± SEM. The * symbol denoted significant difference between each session at the specific time point ($p < 0.05$).

DISCUSSION

The intent of this study was to provide a more detailed characterization of the prolactin responses to exercise (i.e., prolonged endurance cycling) due to the limited number of such findings in the research literature which employed frequent blood sampling protocols. The present findings demonstrate that the strenuous form of exercise used induced significant and persistent elevations in prolactin concentrations. Many of the significant exercise prolactin concentrations approached a 300% elevation over the comparable rest-control session values. The prolactin concentrations became elevated during the exercise session by 45 minutes into the exercise bout. The magnitude of the increases and the time course of these changes are similar to those reported previously (all be it, many such studies have used less frequent bloods sampling protocols) [5, 8, 9].

In contrast to most hormones, prolactin is apparently under chronic negative inhibition with dopamine serving as the inhibiting factor of secretion. Dopamine is secreted into portal blood by hypothalamic neurons, binds to receptors on lactotroph cells which produce prolactin, and inhibits both the synthesis and secretion of the hormone [1]. In addition to tonic inhibition by dopamine, prolactin secretion is positively regulated by several other hormones, including thyroid-releasing hormone, gonadotropins-releasing hormone and vasoactive intestinal polypeptide [1, 2]. In response to exercise, the elevations in prolactin concentrations seem brought about by the removal of the dopamine inhibition effect; although, further work is necessary to clarify and substantiate this point.

The role prolactin plays in responses to exercise is an issue of much debate and continued investigation. There are several possible explanations for why prolactin increases with exercise. First, it is well established that hyperprolactinemic states (acute or chronic) can have suppressive effects on the reproductive systems in men and women [1]. In humans as well as many other species, reproductive function is linked to energy reserves and availability [1, 2]. It is conceivable that prolactin elevations due to exercise serve as a means to signal for a reduction in reproductive function due to the reduced or limited energy available induced by strenuous activity [6, 10]. The exercise prolactin response is transient, but nonetheless is substantial and persistent enough in the early hours of recovery from exercise to perhaps signal such a status change [3]. On the other hand, it is also possible that prolactin is playing a key role in activation of the immune system following exercise. The prolactin receptor is widely expressed by immune cells, and some types of lymphocytes even synthesize and secrete prolactin [1, 2, 4]. These observations suggest that prolactin may act as an autocrine, paracrine as well as endocrine modulator of immune activity [4, 7, 12]. Thus the hormone may serve as a mediator to the post-exercise inflammatory process and as a means to initiate aspects of the process in order to allow recovery-regeneration and adaptation to exercise. The intention of this study was not to elucidate the mechanism or the role of prolactin release to exercise; but the above speculation present plausible explanations as to why the observe response occurred. Future research needs to address these issues much more closely.

To summarize, this study found that the hormone prolactin has a significant and robust elevation in the blood in response to prolonged endurance exercise. The blood levels in this study became significance increased by 45 minutes into the exercise bout and remained so throughout the remainder of the exercise as well as for 30 minutes into recovery. The role prolactin plays in response to exercise is unclear, but may relate to signaling energy usage-status within the body and, or as an immune system activator. Further research is necessary to address the question of what physiological role this hormone has in helping the body to accommodate and adjust to exercise.

REFERENCES

1. Ben-Jonathan N., LaPensee C. R., LaPensee E. W. (2008) What can we learn from rodents about prolactin in humans? Endocrine Rev. 29: 1–41.
2. Brandebourg E. H., Ben-Jonathan N. (2007) Adipocyte prolactin: regulation of release and putative functions. Diab. Obes. Metab. 9: 464–476.
3. Daly W., Seegers C. A., Rubin D. A., Dobridge J. D., Hackney A. C. (2005) Relationship between stress hormones and testosterone with prolonged endurance exercise. Eur. J. Appl. Physiol. 93: 375–380.
4. Dimitrov S., Lange T., Fehm H. L., Born J. (2004) A regulatory role of prolactin, growth hormone, and corticosteroids for human T-cell production of cytokines. Brain Behav. Immun. 18: 368–374.
5. Hackney A. C., Ness R. J., Schreiber A. (1989) Effects of endurance exercise on nocturnal hormone concentrations in males. Chronobiol. Intern. 6: 341–346.
6. Kelesidis T., Mantzoros C. S. (2006) The emerging role of leptin in humans. Pediatr. Endocrinol. Rev. 3: 239–248.
7. Kelly K. W., Weigent D. A., Kooijman R. (2007) Protein hormones and immunity. Brain Behav. Immun. 21: 384–392.
8. McMurray R. G., Hackney A. C. (2000) The endocrine system and exercise. In: Exercise & Sports Science. Editor, W. Garrett & D. Kirkendall. Williams & Wilkins Publisher, pp. 135–162.
9. Piacentini M. F., Meeusen R., Buyse L., DeSchutter G., DeMeirleir K. (2004) Hormonal responses during prolonged exercise are influence by a selective DA/NA reuptake inhibitor. Br. J. Sports Med. 38: 129–133.

10. Sone M., Osamura Y. (2001) Leptin and the pituitary. Pituitary 4: 15–23.
11. TsigosTsigos C., Chrousos G. P. (2002) Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress. J. Psychosom. Res. 53: 865–871.
12. Webster Marketon J. I., Glaser R. (2008) Stress hormones and immune function. Cell. Immun. 252: 16–26.
13. Winter S. J. (1994) Endocrine evaluation of testicular function. Endocrinol. Metab. Clin. North Am. 23: 709–723.

Correspondence to:
Anthony C. Hackney
University of North Carolina
CB # 8700 – Fetzer Building
Chapel Hill, North Carolina, 27599–8700
USA

SELF-PERCEIVED PHYSICAL AND HEALTH CONDITION OF OLDER PERSONS (AGED 65–75)

A. Kaupuzs[1], **V. Larins**[2]
[1]Rezekne Higher Education Institution
[2]Latvian Academy of Sport Education
Latvia

ABSTRACT

To study health habits is the way how to get information about population's attitude and knowledge about health. The latest 2006 FINBALT monitoring questionnaire contains full spectrum of questions about health care in Latvia and the Baltic region. The aim of the current review paper is to compare some FINBALT results between the states and regions and find out new facts about self-perceived physical and health condition of older persons (65 – 75 years old). The data from two 2006 FINBALT Health Monitor for adults aged 55–64 surveys were used to make comparisons in physical activities and health trends between Latvia and Finland. To find out new facts about older persons (65–75 years old) we did a survey of visitors of pensioner day centres in Rezekne and Daugavpils towns. Our survey shows that there is no major difference between the results we got in pensioner day centres and in Latvia during this research, but there is a dramatic difference with the results which were got in Finland. Latvian inhabitants' self-perceived physical and health condition results are worse than in Finland. In Latvia for older people sedentary life is common (persons who practice 30 minutes long physical exercise at least 2–3 times per week in Finland are 74%, in Latvia – 25%).

Key words: FINBALT, health, older persons, physical condition

INTRODUCTION

Rapid population aging will create major challenges for states and economics over next half-century [4]. One of the main factors, which determine the stage of development of society: how it cares about old people. A state has to know about old people's life, abilities of adaptation in changes of social processes, about possibilities to examine their health etc. Among the factors influencing health, behaviour essentially affects health and well-being of each individual and the population. Lifestyle patterns such as nutritional habits, physical activity and smoking or heavy alcohol consumption influence premature mortality [13]. In Latvia as in many East European states the mortality rate has been increasing. Currently the average life expectancy at birth in Latvia is 65 years for males and 76 for females which is one of the lowest in all Europe [3]. The attitude of society to old people characterizes level of society's civilization. Unfortunately Latvia is still running behind the other EU countries, where this kind of work is being taken. In other EU countries there are even special research institutes for old people, and they take care of old people's life conditions. Unfortunately in Latvia old people have to rely on their families and themselves.

A human in the same way as each living being born, comes of age, becomes old and dies. Aging can also be defined as a progressive or a gradual functional decline of physiological function with age [13]. In humans, our body's functional decline tends to begin after the sexual peak, roughly at the age 20. Physical abilities: endurance, strength and speed are the best at the age of 30–35, after this age they are decreasing [2, 9, 16]. Aging is characterized by changes in appearance, such as a gradual reduction in height and weight loss due to loss of muscle and bone mass, a lower metabolic rate, lower reaction times, declines in certain memory functions, a functional decline in audition and vision, declines in immune functions, declines in exercise performance, and multiple endocrine changes [4, 14].

Exercise is an important tool that can provide tremendous benefits to both body and soul at any age. This is particularly relevant in cases where the body faces additional challenges, including those appearing in the later years of life [1, 10]. The promotion of health through increased physical activity has become a national public health objective for both children and older. To study health habits is the way how to get information about population' attitude and knowledge about health. This information promotes behaviour risk analysis and shows how it changes in the course of time.

MATERIALS AND METHODS

There are some sources of literature where we can find the information about the Latvian people who have changed their free time activities. Elderly people become more interested in the questions of healthy lifestyle. Many people admit positive influence of exercises on physical, social and mental well-being. In our research we wanted to look more closely at three of these aspects: physical activities of old people, self – assessment of health and physical condition and habits of their free time activities. For this purpose a questionnaire has been made. The visitors of Rezekne and Daugavpils town pensioner's daytime centres answered the questions of this questionnaire in the period from October to December 2007. In this period 100 questionnaires were given, from which 93 were admitted as suitable for data processing. The questionnaire included also some similar questions as in FINBALT health's monitoring questionnaire. FINBALT Health Monitor is a collaborative system for monitoring health related behaviour, practices and lifestyles. The main object of the FINBALT project is a mailed questionnaire to nationally representative samples [5]. The sharp contrast in health conditions around the Baltic Sea in the early 1990s – the increase of life expectancy in Finland vs. decrease in the Baltic countries – was the starting point of Finbalt Health Monitor project. The Finnish national monitoring system which started in 1978 was focused on health behaviour and subjective health. In collaboration with the National Public Health Institute of Finland, the health behaviour monitoring system was launched in Estonia in 1990. In Lithuania the first national health behaviour survey was carried out in 1994, and thereafter, similarly to Estonia every second year. Latvia joined the project in 1997. The survey was carried out simultaneously in all Baltic countries and Finland for the first time in spring 1998. Its purpose is from peripheral routine data of statistics to get information about self –assessment of health, behaviour connected with health, use of health care and preventative activity. It is necessary to gather information about the most important health problems in the state, to show their geographical and demographical extension, its dynamics, as well as to state strategical priorities of the sectors. In our opinion it is useful to compare the achieved results in our regional survey with FINBALT data which display the situation both in the state and abroad.

RESULTS

Analysing the questionnaires it was stated that females have a very large priority between the respondents – 84%, which is explained by offered service in pensioner's day centre and psychological feature at that age. For the results of the data to be objective only those questionnaires which were filled out by women were used for further analysis. The average age of the respondents was 68. Aging level between the respondents was from the age 63 to 81. The last age level in FINBALT monitoring is 55 to 64. In this way we can compare the tendency of changes in aging [5, 6].

Analysing the answers to the question: "What is your self-perceived health condition?" the following results were achieved – only 9.7% admitted their health as good and rather good; 71% marked "average" and 19.3% admitted that they have serious health problems (Figure 1).

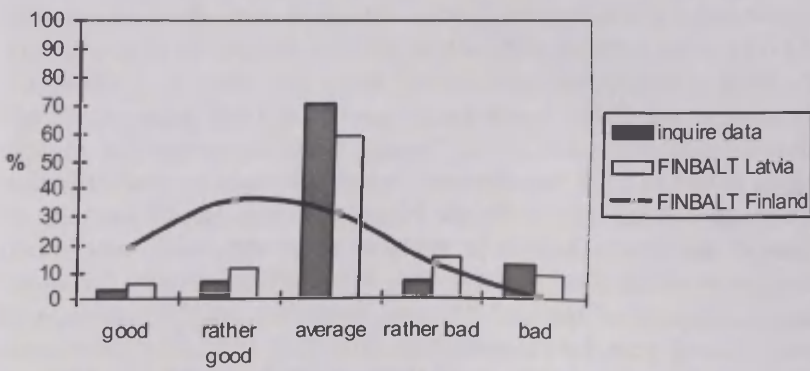


Figure 1. What is your self-perceived health condition?

The fourth part (24.2%) of the respondents of the questionnaire evaluated their physical condition as deficient. The largest part of the respondents – 65.5% chose "average" index. But only approximately each tenth (10.3%) of the participants evaluated their physical condition as satisfactory (Figure 2). The data obtained by us in both questions are very similar to the results of FINBALT Latvia, while they are dramatically different from the answers of the inhabitants of Finland. From the analysis of the results we can conclude that the inhabitants of Latvia have worse physical and health self–perceived condition than the inhabitants of Finland. The older people of Latvia mostly marked these parameters as average or worse.

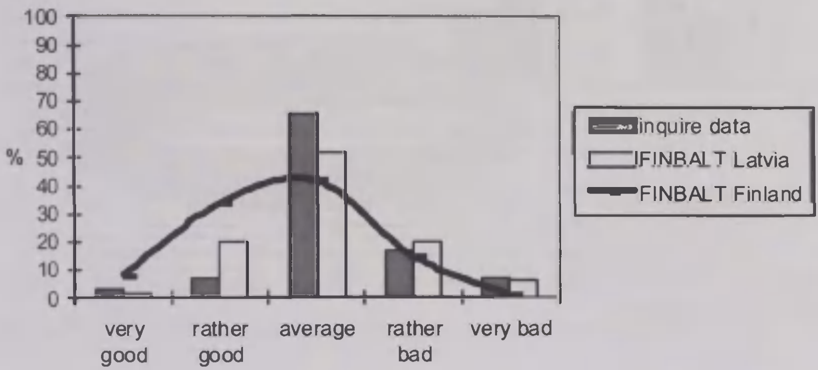


Figure 2. What is your self-perceived physical condition?

To collect the information about pensioner's daytime physical activities the answers to the questions about sportive habits were evaluated (Figures 3 and 4). As we can see from the Figure 3, the inhabitants of Latvia are less active and engage in less active exercises in their free time. Women in Finland spend walking and doing physical exercises at least 4 hours in a week in the most part of their free time.

The answers to the question "How often do you make at least 30 minutes long physical exercises to easy breath lack or sweat during leisure hours?" show that the most part of the inhabitants of Finland (73.9%) do their necessary volume of physical activities per week. From our questionnaire data you can see inadequately high result to the question that 27.5% of the respondents do 30 minutes long physical activities every day. In our opinion these results are unbelievable, because they are not connected with other results from the previous questions. Probably the respondents because of their age understand the identified physical activities until light shortness of breath lack as physically active work, but it is not applied to regular, advised physical activities.

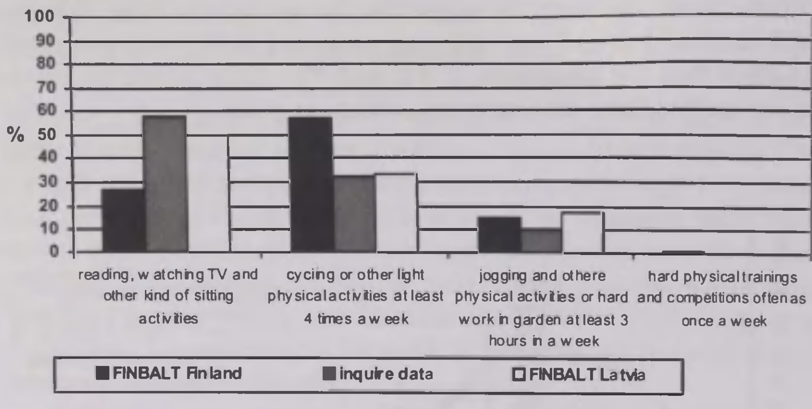


Figure 3. Which of the following descriptions mostly conform to your free time activities?

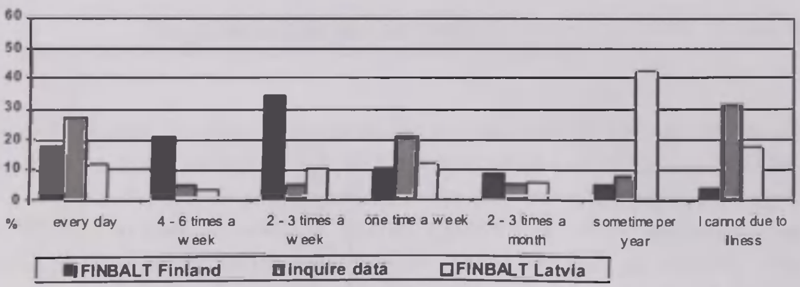


Figure 4. How often do you make at least 30 minutes long physical exercises to easy breath lack or sweat during leisure hours?

The concluding part of the questionnaire included the questions about the respondent attitude towards physical activities. 74 % of the respondents agree that physical activities are a good possibility to improve and maintain health (Figure 5). It shows that people realize the necessity of exercises on week days, however the previous results are opposite. It probably could be explained by insufficient offer of sport facilities for this age and by the lack of encouragement system. Because the answers to the question (Figure 6) show that people want to take part in physical activities, but they do not gain sufficient social assistance to realize it. More than one half – 55 % of the respondents would gladly take part in physical activities and only 32 % of the respondents think that it is not an actual question.

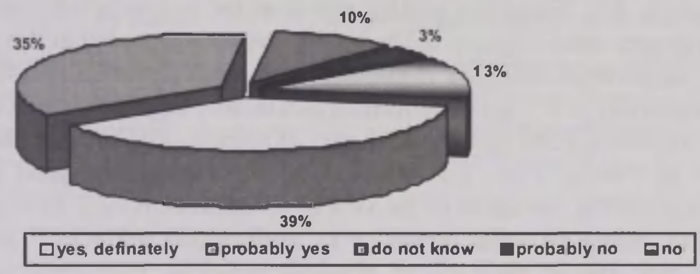


Figure 5. Can physical exercises retain or improve your health?

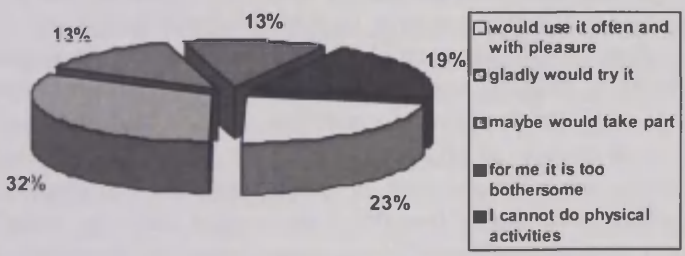


Figure 6. If somebody would offer you to do physical activities

DISCUSSION

Hypodynamia is shortage of exercise, which causes changes in a person's body. "Physical inactivity destroys human body and mind", wrote Aristotle [1]. People nowadays are unhealthy because of lack of exercise. Exercise enforces metabolism, and each organs activity depends on metabolism. Scientists assert that permanent immobility is one of the relevant causes, which engenders organism's premature senility. It is closely connected with the aging of the circulatory system [8, 15]. There is a saying: one is as old as his blood – vessels. But changes arise not only in the blood – vessels, but also in the heart. Lack of physical activities is admitted as one of the main risk factors of chronically non – communicable disease development, which raises approximately 3.5% of different kinds of diseases and to 10% cases of death in Europe [11]. Emotive is also the high economical price, which is paid in the result of the lack of physical activities. Findings in research about physical activities in Switzerland and Great Britain show that due to the lack of physical activities they have to pay approximately 150–300 euro per one inhabitant [7]. The increase of physical activities would improve health of all society, as well as it would reduce expenses, which we pay for the lack of physical activities. As the data show (Table 1) that physical activities and self-assessment of health condition by the inhabitants of Latvia are decreasing from 2000, however in Finland these results are several times higher [5, 6]. Along with the increased evidence associating lower level of physical activity with higher risk of death from heart disease [8, 17], the data from longitudinal studies have emerged indicating the influence of physical activity on longevity and mortality from other chronic disease such as cancer, diabetes, hypertension, and osteoporosis [14]. Major benefits from regular exercise include the following: better handling of blood sugar, improved breathing, better endurance, improved balance, greater strength, stronger bones, improved sense of well-being, and better sleep [15].

Table 1. Self perceived health condition and physical activity.

Year of questionnaire	Proportion of respondents which do physical exercise for 30 min. **at least** 2–3 times a week **In Latvia (%)**	Proportion of respondents self-perceived of health condition is good or rather good. **In Latvia (%)**	Proportion of respondents which do physical exercise for 30 min **at least** 2–3 times a week. **In Finland (%)**	Proportion of respondents self-perceived of health condition is good or rather good. **In Finland (%)**
1998	28	16	66	49
2000	31	20	68	52
2002	28	17	68	55
2004	28	17	68	56
2006	25	17	74	55

Our survey shows that there are no major differences between the results we got in the regional pensioner day centres and in Latvia, but there is a dramatic difference with the results which were obtained in Finland. People of Finland care a lot more about their physical condition in comparison to people of Latvia. As it shows, more than three fourths of Finland people who participated in the survey exercise at least two or three times per week. In order to maintain a healthy body this amount of exercising is required. Latvia survey results show that the most often answer is "some times per year". In the survey of the day centre visitors in our opinion they have misunderstood the meaning of the question "*How often do you make at least 30 minutes long physical exercises to easy breath lack or sweat during leisure hours?*", because their answers dramatically differ from the answers from other regions of Latvia. In our opinion this happens mostly because in the second part of the question there are words "easy breath lack" which are recognized as key words. Also the self-assessment of health status in Finland is better than in Latvia. We included also some questions to investigate the attitude to physical activities of our respondents. Most part of the respondents agrees that exercise can retain or improve health. But if we compare it to the previous results, we can conclude that they for some reasons do not do that. That shows us new aims and ways for investigation.

From this we can conclude that aging is not the time when we give up as lost and complain about illness, in contrary, we have to find the way out to feel fresh and cheerful in old age. One of the ways is to do regular exercises which will help to keep fit and treat different illnesses. But we should be aware that a 70 years old person cannot do all complicated exercises, it can make state of health worse. Many people are afraid of sports activities because they do not feel sure about themselves; they know that they will not be able to do all exercises. But we have to make a system and we have to deal with this problem in general. There are some main aspects for it: to prepare specialists, to make programmes and facilities where to realise them, to popularize physical activities in mass media. Society has to understand that the most important thing for old age people is to add life for years not years for life [12].

CONCLUSIONS

1. Natural ageing begins around 30; it is affected by lifestyle, physical activities, and features of individuality. In ageing process organism's dynamical indices at the age of 60 decrease per 0.8–1%, after 60 – per about 2% in a year.
2. As the data show there are no relevant differences between the results of answers of FINBALT questionnaire in Latvia and the results we got in the regional pensioner day centres.
3. Analysing the data of FINBALT monitoring and comparing our achieved questionnaire data to Latvian and Finland unitary questionnaire results, we can conclude – the inhabitants of Latvia have worse self – perceived physical condition than in Finland. More than three quarters of old people in Latvia mostly marked these parameters as average or worse. However in Finland 55% of the respondents value their health as good and very good.
4. In Latvia for older people sedentary life is common and for most of the respondents sports activities are not actual on weekdays. For comparison in Finland the proportion of the respondents who do physical exercises 2–3 times a week in their free time is 74%, in Latvia – 25%.
5. Analysing FINBALT Latvia data of the questionnaire from 1998 to 2006 we have come to the conclusion that there is a tendency for physical activity to decrease in this period of age.

6. Analysing the answers to the questions about the attitude to physical activity, we can conclude that the inhabitants consider it necessary, but there is the lack of social support for its realisation.
7. Promotion of physical activities would have been one of society's health priorities, including all spheres. Programme of society's health policy on promotion of physical activities should be planned in long – term with definite aim and definite indicators.

REFERENCES

1. Auziņa I. (1999) Seniori un fitness. Veselība/Sveiks un vesels Nr. 7, 23–25.
2. Auziņa I., Saulīte-Zandere I. (2000) Lielā fitnesa grāmata. Rīga: Jumava, 225.
3. Central statistical Bureau of Latvia (2007). Statistical Yearbook of Latvia 2007. Riga
4. Hayflick L. (2000) The future of ageing. Nature 408: 267–269.
5. Health Behaviour among Finnish Adults http://www.ktl.fi/portal/english/research_people_programs/health_promotion_and_chronic_disease_prevention/projects/finbalt/publications/
6. Health Behaviour among Latvian Adult Population, 2006. http://www.ktl.fi/portal/english/research_people_programs/health_promotion_and_chronic_disease_prevention/projects/finbalt/publications/
7. Health statistics Key data on health 2002 http://ec.europa.eu/health/ph_information/dissemination/reporting/eurostat_health2002_1_en.pdf
8. Hein H. O., Suadicani P., Gyntelberg F. (1992) Physical fitness or physical activity as a predictor of ischaemic heart disease? A 17-year follow-up in the Copenhagen Male Study. J. Intern. Med. 232: 471–479.
9. Kovaļčika K. (2001) Pilns ceļvedis skriešanā sievietēm. Rīga: Kontinents, 461.
10. Kūpers K. (1990) Aerobika veselībai. Rīga: Zinātne, 235.
11. Ministry of Welfare (1997). Latvia's report to the WHO Regional Office for Europe on the third evaluation of progress towards health for all in the European Region of WHO (1996–1997) (unpublished, 1997).
12. Monte T. (2004) Staying young: how prevent, slow or reverse more than 60 sings of aging. Rodale Press.

13. Partridge L., Mangel M. (1999) Messages from mortality: the evolution of death rates in the old. Trends in Ecology and Evolution 14: 438–442.
14. Steffen L. M., Arnett D. K., Blackburn H. (2006) Population trends in leisure-time physical activity: Minnesota Heart Survey, 1980–2000. Med. Sci. Sports Exerc. 38: 1716–1723.
15. Strehler B. L. (1999) Time, Cells, and Aging. Demetriades Brothers, Larnaca.
16. Valtneris A. (1997) Cilvēka fizioloģijas zināšanas – veselības mācības pamats. Sveiks un vesels Nr. 11, 22–23.
17. Williams P. T. (2003) The illusion of improved physical fitness and reduced mortality. Med. Sei. Sports Exerc. 35: 736–740.

Correspondence to:
Aivars Kaupuzs
Rezekne Higher Education Institution
Atbrivošanas Aleja 115
Rezekne
LV–4600
Latvia

Acta Kinesiologiae Universitatis Tartuensis. 2008, Vol. 13

NO EFFECT OF MUSCLE FIBER TYPE ON MECHANICAL EFFICIENCY DURING CYCLE EXERCISE AT 1.5 HZ

J. I. Medbø

National Institute of Occupational Health, Oslo, Norway

ABSTRACT

The mechanical efficiency has been determined for 23 healthy young men to study possible effects of muscle fiber type on efficiency during cycle exercise. Each subject cycled for 10 min at in average 19 different powers ranging from ≈1.0 to 4.6 W kg^{-1} (70–370 W) while the pedalling frequency was kept constant at 1.5 Hz. The rate of energy release was determined from the steady state O_2 uptake measured near the end of each 10 min exercise period. Delta efficiency was taken as the inverse of the slope of regression of O_2 uptake on power (dP/dnO_2). Gross efficiency at 3 W kg^{-1} was established, and finally, the efficiency was taken from each subject's slope of O_2 uptake versus power using a common, fixed *Y*-intercept. Muscle biopsies were taken from the lateral portion of the knee extensor muscle, and muscle fibers were classified as type I or type II. The proportion of type I fibers was 0.50 ± 0.13 (mean ± *s*), delta efficiency was 0.262 ± 0.010, and gross efficiency was 0.213 ± 0.005. There was no significant correlation between any efficiency measure and the proportion of type I fibers. A two-sided 95% confidence interval on the data suggests that if the efficiency of the two fiber types differed, the difference was less than 12%. For the same subject the efficiency did not differ more than a few percents between low powers where type II fibers may be little engaged and high powers where both fiber types are active. The data therefore support the idea that the efficiency does not differ between type I and type II fibers during cycling at 1.5 Hz.

Key words: bicycle ergometry tests, mechanical efficiency, muscle fiber types, oxygen uptake, power, statistical analysis, submaximal exercise

INTRODUCTION

During exercise chemical energy is converted to mechanical work in active muscle fibers. The ratio between the work done and the energy released to do the work is defined as the mechanical efficiency. There are two main fiber types in human skeletal muscle, but there is no general agreement about the efficiency of each fiber type. The process of shortening at the molecular level is the same: A muscle carries out work by cross-bridge cycling [19]. Since one cross-bridge cycle requires one ATP-molecule apparently irrespective of muscle fiber type, it is conceivable that the two main fiber types work equally efficiently. That is the working hypothesis for this study.

During exercise lasting more than 1 h and carried out at moderate intensities there is a gradual recruitment of type II fibers in the quadriceps muscle as judged from changes in glycogen concentration in single fibers [13, 14, 43, 44]. Despite this, there was no increase in the O_2 uptake [44], which suggests that type II fibers worked as efficiently as type I fibers do during cycling. Different studies relating mechanical efficiency to the proportion of muscle fiber types in the knee extensor muscle have on the other hand suggested either that type II fibers work more efficiently than type I fibers do at high pedalling rates [38], that both fiber types work equally efficiently [5], or that type I fibers work more efficiently than type II fibers do [8]. In one study type I fibers appeared more efficient than type II fibers or there was no difference between the fiber types depending on the pedalling rate chosen [15]. Thus, the effect of muscle fiber type on mechanical efficiency during cycle exercise is not established. One problem is how the efficiency is determined. First, the experimental conditions were not well standardized in the studies above and may have varied systematically between subjects with different proportions of fiber types. Moreover, it requires quite extensive experiments to obtain reliable relationships between the steady state O_2 uptake and exercise intensity [31]. Thus, inadequate experimental approaches may have caused the inconclusive results mentioned above.

Further research is needed. The efficiency during cycle exercise has been related to the proportion of type I fibers in an active muscle. Since results of former studies may have been influenced by experimental shortcomings, care was taken concerning the experimental design. Since type II fibers may not be active below a certain recruitment threshold, that threshold was estimated for each subject. The relationships between O_2 uptake versus power were examined. A problem that has not been considered in former studies is that muscle fiber type is usually determined only in one muscle, while many muscles are working during most exercises. A re-examination of data of Johnson and coworkers [21] shows that classification of fibers in one muscle provides essential information on fiber type proportions in other muscles too (see the appendix). Preliminary results from part of the study have been presented elsewhere [27].

SUBJECTS AND METHODS

Subjects

23 healthy men 25 ± 4 yr old (mean ± *s*), 1.81 ± 0.07 m tall, weighing 76 ± 8 kg and with a maximal O_2 uptake of 40 ± 4 µmol kg^{-1} s^{-1} (54 ± 5 ml_{STPD} kg^{-1} min^{-1}) volunteer as subjects in the studies. Most of the subjects were physically active students. The subjects underwent a medical examination and were thoroughly informed both orally and in writing about the purpose of the experiments and its practical details before they gave their written consent to participate. The data in this study are taken from larger series of experiments that have been approved by the institute's ethics committee or by the Ethics Committee of Health Region 2 in Norway.

Procedures

The exercise was done on a Krogh-type cycle ergometer [24], modified with modern electronic control and recordings, and all exercise was carried out at a pedalling frequency of 1.5 Hz. This ergometer adjusts the breaking force to equal the force of gravity of a preset load placed on one side of a balance. The frequency was continuously shown to the subjects on an analog instrument, and the actual power during 10 min exercise deviated from the preset by < 0.1 W

(≈0.05 %). The ergometer was equipped with drop handle bars and pedals without foot straps. Consequently work on the pedals could only be done during the downstroke.

Individual relationships between power and the O_2 demand (rate of energy release expressed in O_2 units) were established by measuring the steady state O_2 uptake from 8 to 10 min of exercise at a constant power below the maximal O_2 uptake. This was done 19 ± 9 times (range: 9–43) for each subject at powers ranging from 30% to ≈90% of the maximal O_2 uptake (0.8–4.6 W kg^{-1}, 50–370 W). The subjects did 2–5 rides of 10 min duration each day with ≈5 min rest between each ride, and within each day exercises were carried out at increasing power.

METHODS

The maximal O_2 uptake was determined by the levelling-off criterion [39]. Fractions of O_2 and CO_2 in the expired air were measured on a Scholander gas analyzer [34] or on an automatic system (CO_2 on an analyzer from Simrad Optronics, Oslo, Norway or a CD-3A analyser with a P-61B infrared-type CO_2 sensor from Applied Electrochemistry, Pittsburgh, PA, USA; O_2 on an S 3A/I from Applied Electrochemistry). Gas volumes were measured in a wet, Tissot-type spirometer [41] or by an S430-A ventilation measure system with a K520–C521 flow transducer (Applied Electrochemistry) while the air temperature was measured simultaneously by a thermometer. The air pressure was recorded to the nearest hectopascal by a mercury barometer calibrated against high-precision instruments at the Norwegian Institute of Meteorology. From each subject at least four muscle biopsies were taken from the mid portion of the lateral portion of the knee extensor muscle (*m. vastus lateralis*), and 200 fibers or more in each biopsy were classified as type I or type II to obtain the subjects' proportion of each fiber type in that muscle. This protocol fulfills recommendations for obtaining reliable estimates of the proportion of each fiber type in a muscle [4, 10, 26].

The muscle fibers were classified by a histochemical method where serial sections of the biopsies were stained for myosin ATP-ase activity after different pre-incubations as described in detail elsewhere [42, 44]. For 13 of the subjects type II fibers were also subclassified histochemically as type IIA, type IIAB, or type IIB according to a system worked out at this institute [42]. Fibers here called type IIB probably corresponds to those usually called human type IIX now, and likewise, those here called type IIAB corresponds to those now called type IIAX by most researchers. Since a formal comparison of the institute's method with more recent and common classifications has not been carried out, the older naming is used in this paper.

Calculations and statistics

Efficiency measures. For each subject a relationship between steady state O_2 uptake and power was established by linear regression. The delta mechanical efficiency was calculated from the inverse of the regression's slope, that is from dP/dnO_2, where dnO_2 is the increment in steady state O_2 uptake associated with an increament dP in power. The O_2 uptake at 3 W kg^{-1} was estimated from each subject's regression line, and the gross efficiency was calculated as P/nO_2 where P is the power of 3 W kg^{-1} and nO_2 is the O_2 demand at this power. An estimate from the regression line was preferred to a single measurement since that reduced the effect of errors in single measurements from >0.7 μmol kg^{-1} s^{-1} to 0.25 ± 0.09 μmol kg^{-1} s^{-1}, that is, by a factor of three. The relative error of the slope and consequently also the gross efficiency was 0.008 ± 0.003. A third, robust measure of the efficiency was taken as follows: The *Y*-intercept varies between subjects, but the variation is probably largely of random nature [29]. An error in the *Y*-intercept will affect the slope too since the two parameters are usually (negatively) correlated [45]. Thus, an erroneously large (small) *Y*-intercept is associated with an erroneously small (large) slope that again will affect the calculated efficiency. A fixed *Y*-intercept may give more reliable relationships between O_2 demand and exercise intensity [29]. Therefore, the mean of the subjects' *Y*-intercept was chosen, and for each subject a linear regression of steady state O_2 uptake on power was calculated using this fixed *Y*-intercept [6]. A second measure of the delta efficiency was taken from the slope so obtained for each subject, that is as dP/dnO_2 as above.

The respiratory exchange ratio during the submaximal 10 min pretests averaged 0.93 and varied little between subjects and experiments. One mole of O_2 was consequently set equal to 465 kJ [25].

Estimation of recruitment threshold of type II fibers. Type I fibers seem to be recruited before type II fibers [13, 14, 43, 44] in agreement with Henneman's size principle [17]. Data on glycogen depletion in single muscle fibers have shown that the proportion of muscle fibers in the lateral portion of the knee extensor muscle recruited during cycling may equal the exercise intensity relative to maximal O_2 uptake [43]. The latter observation means that a subject with 40% or 70% of type I fibers recruits few or no type II fibers in that muscle during the first 20 min of exercise, as long as the exercise intensity is less than 40% or 70%, respectively, of maximal O_2 uptake. At higher intensities all type I and in addition a significant part of type II fibers in the knee extensor muscle are recruited from the onset of exercise (see Fig. 5 in Ref [43]). The recruitment threshold of type II fibers may therefore differ between subjects with different proportions of type II fibers. This finding has been used to estimate individual recruitment thresholds for type II fibers, and a separate examination showed that this estimate has a statistical error of 0.3 W kg^{-1} (25 W, corresponding to 9% of the maximal O_2 uptake). For subjects with enough measurements of O_2 uptake versus power above or below the estimated thresholds according to [31], separate regressions were calculated, and the slopes so obtained were compared with those of the full data set.

Statistics. Data are given as individual results or as mean ± *s* (standard deviation, SD). Correlations between two variables have been expressed by the common Pearson's correlation coefficient (*r*). Linear regressions were calculated by common least square estimators of the slope and *Y*-intercept or by using a fixed *Y*-intercept [6]. The scatter around the regression line ($s_{Y|x}$) has been used as a measure of the goodness of the fit, and in addition the error of the slope (s_b) is used. A possible breakpoint in each subject's relationship was examined as proposed by Jones and Molitoris [22]. Statistical tests were carried out in a spreadsheet, and all tests were carried out two-sided since different studies have suggested that type II fibers may work either more efficiently or less efficiently that type I fibers do.

RESULTS

O_2 uptake versus power. Delta mechanical efficiency

The steady state O_2 uptake rose almost linearly with power at all sub-maximal intensities above ≈1 W kg^{-1} (≈70 W; Figure 1). The slope was 8.2 ± 0.3 μmol J^{-1}, which corresponds to a delta efficiency of 0.262 ± 0.010. The error of the slope (s_b) was 0.22 ± 0.07 μmol J^{-1}. This corresponds to an error of 0.007 in the efficiency or <3% of the mean of 0.262 in single determinations of the mechanical efficiency.

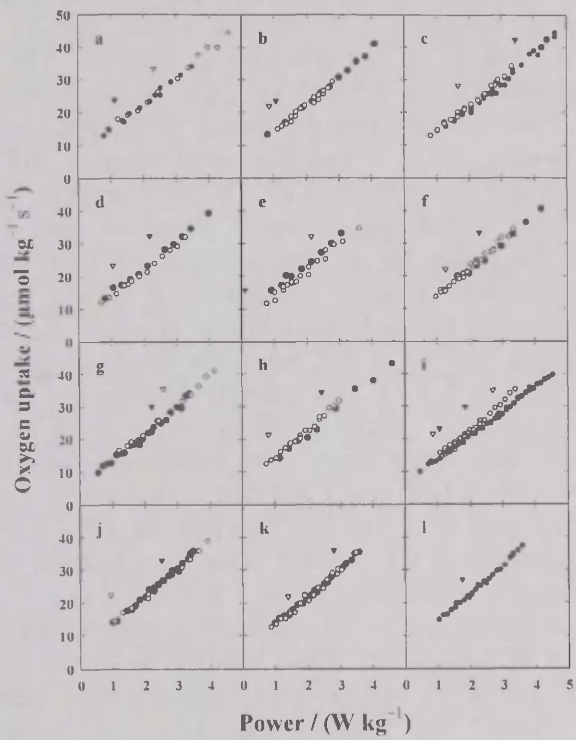


Figure 1. Steady-state O_2 uptake versus power for 23 subjects cycling repeatedly for 10 min at different powers. The subjects had different proportions of type I fibers in their knee extensor muscle. Type I fibers are probably recruited before type II fibers, and thresholds of recruiting type II fibers estimated as explained in the methods, are shown for each subject by the triangles.

The Y-intercept of the regression lines was 5.6 ± 0.9 µmol kg^{-1} s^{-1} (around twice the resting O_2 uptake in a supine position). The statistical error in a single estimated Y-intercept averaged 0.5 µmol kg^{-1} s^{-1}. The error of regression (scatter around the regression lines, $s_{Y|x}$) was 0.7 ± 0.2 µmol kg^{-1} s^{-1}, and the correlation coefficient was 0.995 ± 0.003.

Efficiency at low and high powers

Type II fibers may be little active at low powers [14, 40, 43]. A threshold for recruitment of type II fibers was therefore estimated for each subject as explained in the method section, and the estimated thresholds are shown by the triangles in Figure 1. The estimated threshold appeared at 1.8 ± 0.8 W kg^{-1} and ranged between 0.1 and 3.4 W kg^{-1}. There were minimal differences in efficiency between low and high powers. First, a two-line approximation did not give significantly better fits to the data ($P = 0.25$). Moreover, the slope of regression lines above the estimated threshold was 1.04 ± 0.03 ($n = 13$) of the slopes for all measurements for each subject with enough measurement to allow calculation of reliable relationships above the estimated threshold according to proposed directions [31]. A corresponding analysis of data below the threshold on six subjects gave a ratio of 0.97 ± 0.03. This analysis suggests that for the same subject the mechanical efficiency did not differ much between low powers where only type I fibers were presumably working and at higher powers where both type I and type II fibers were working (see the arrows in Figure 1). In line with this, pairs of subjects with widely different proportions of type I fibers in the knee extensor muscle had similar mechanical efficiencies (Figure 1 a, c–f, h, j, k).

It could be argued that not all relationships were strictly linear. For example, that of subject RN (filled symbols in Figure 1c) shows a slight convex curvature. Second-order curve fits were therefore also examined. These fits reduced the error of regression by 0.10 ± 0.10 µmol O_2 kg^{-1} s^{-1} (14%, from 0.7 to 0.6 µmol O_2 kg^{-1} s^{-1}). However, for four subjects second-order fits actually increased the error of regression slightly. Moreover, both the variability and error in the estimated Y-intercepts rose by a factor of 2.5. Finally, simulations where single measurements of the O_2 uptake were excluded changed the outcome of second-order fits considerably, showing that these fits were not numerically stable.

Efficiency versus muscle fiber type

The proportion of type I fibers in the lateral portion of the knee extensor muscle was 0.50 ± 0.13, and the error in the single determination of fiber type proportion was 0.036. There was no statistically significant relationship between proportion of type I fibers in this muscle and mechanical efficiency taken from the slope (delta efficiency, $r = -0.36$; $P = 0.09$; Figure 2 a). However, the negative correlation means that subjects with a high proportion of type I-fibers tended to work less efficiently than subjects with less type I-fibers as judged from the delta efficiency.

Two other and presumably more robust measures of efficiency were also calculated and related to the proportion of type I fibers. First, the gross efficiency of 0.213 ± 0.005 at a power of 3 W kg^{-1} did not correlate significantly to the proportion of type I fibers in the knee extensor muscle ($r = 0.26$, $P = 0.24$; Figure 2 b).

Denoting the correlation coefficient r, the Y-intercept Y_0 and the slope b, the correlation $r(Y_0, b) = -0{,}94$ for the present data calculated according to [45], and for all *i*ndividual correlations $r_i(Y_0, b) < -0{,}9$. Thus, an erroneously large (small) Y-intercept was associated with an erroneously small (large) slope, which again will affect the delta efficiency. The individual Y-intercepts did not vary much more than what can be ascribed to the statistical error in single estimates, which is compatible with the idea that the observed differences in Y-intercepts between subjects were largely of random origin. To minimize random effects on the calculated delta efficiency and thus to get another robust efficiency measure, the slope of regression of O_2 uptake on power was calculated using a fixed Y-intercept of 5.6 μmol kg^{-1} s^{-1} (the mean for the 23 subjects). The slope was still 8.2 ± 0.3 μmol O_2 J^{-1}, and the error of regression was 0.7 ± 0.2 μmol kg^{-1} s^{-1} (unchanged), but the error of the slope was reduced to 0.08 ± 0.03 μmol J^{-1}, that is by 64%. The efficiency calculated this way was still 0.262 ± 0.010, but the error in single efficiencies was now 0.0025 or less than 1% of 0.26. That efficiency measure did not correlate to the proportion of type I fibers ($r = 0.30$, $P = 0.17$; Figure 2 c).

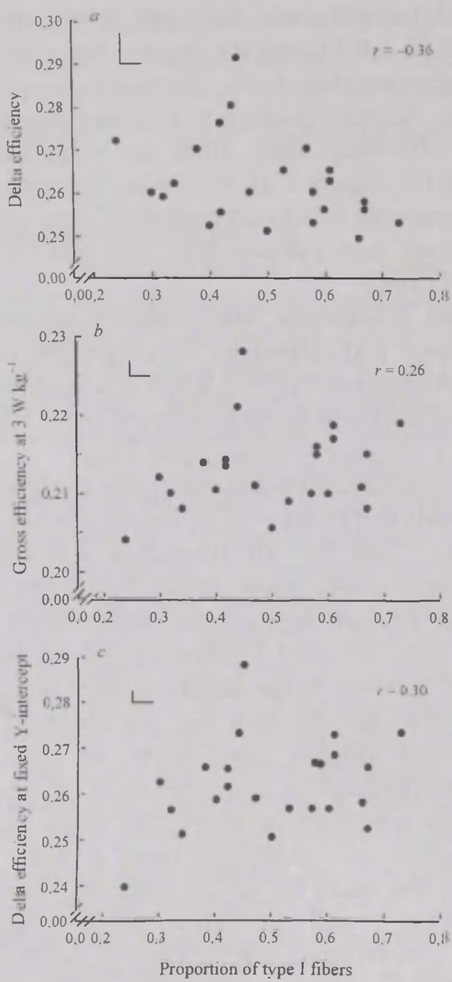


Figure 2. Mechanical efficiency versus proportion of type I fibers in the lateral portion of the knee extensor muscle. *a*, delta efficiency versus fiber type proportion; *b*, gross efficiency at 3 W kg^{-1} versus fiber type proportion; *c*, delta efficiency using a common, fixed Y-intercept versus fiber type proportion. The data are from 23 subjects who cycled repeatedly for 10 min at different powers while the steady state O_2 uptake was measured near the end of exercise. The right-angle mark (L) in each panel shows the statistical or analytical error (*s*) in single determinations of fiber type proportion and efficiency, respectively.

Type II fibers were further subclassified for 13 subjects, and it appeared that 62% of the type II fibers were of type IIA (33% of all fibers), 10% were of type IIAB (5% of all), and 28% were of type IIB (15% of all). It should be noted that only eight subjects had more than 10% of type IIB fibers. The proportion of type IIB-fibers correlated positively to the delta efficiency ($r = 0.57$; $P = 0.04$) but not to the other two and more robust efficiency measures ($|r| \leq 0.07$; $P > 0.8$).

Extrapolation to zero and hundred percent of type I fibers

To estimate the efficiency of type I and type II fibers relationships of efficiency versus fiber type proportion may be extrapolated to zero and hundred percent type I fibers (or type II fibers). Three different efficiency measures gave somewhat different correlations to the proportions of type I fibers. Moreover, an examination of the data shows that for one extreme subject (SRS) with only 24% type I fibers the position relative to the other subjects varied between 1 SD above the average (delta efficiency, Figure 2 a) to around 2 SD below the average (gross efficiency and delta efficiency using a common *Y*-intercept; Figure 2 b and c; see the leftmost point in each panel in Figure 2). The relationships for this subject were based on only nine measurements of steady state O_2 uptake and is thus less reliable than those for most of the other subjects. Recalculating the relationships after excluding the data of SRS gave correlations $r \leq 0.12$ ($P = 0.6$) for gross efficiency and delta efficiency using a fixed *Y*-intercept to the proportion of type I fibers. Exclusion of the data of SRS had less effect on the correlation of delta efficiency to proportion of type I fibers ($r = -0.31$; $P = 0.16$).

Therefore, in further analyses the slope of regression of efficiency on proportion of type I fibers was set to zero, corresponding to zero correlation. The error of the slope of regression of delta efficiency using a common, fixed *Y*-intercept on proportion of fiber type was 0.0154 and somewhat less for the other two efficiency measures. Using this value for the error of the slope gives the interval [–0.032, +0.032] as a two-sided 95% confidence interval around a slope of zero. Extrapolating the upper end of the confidence interval to zero and 100% type I fibers gives efficiencies of 0.246 (0% type I fibers) and 0.278 (100% type I fibers). The ratio of these two values is 0.88. A corresponding extrapolation of the lower end of the confidence interval or for zero and 100% type II fibers gives the same result. Thus, the data suggest that if the efficiency of the two main fiber types differed in the present study, the difference is no more than 12%. These calculations were repeated using data of the other two efficiency measures. Those calculations gave somewhat narrower confidence intervals.

DISCUSSION

The delta efficiency averaged 0.26 while the gross efficiency at a power of 3 W kg^{-1} was 0.21. The efficiency varied between subjects, but it was not related to the proportion of type I fibers in the knee extensor muscle. Delta efficiency did not differ much between low and high powers despite a probably larger contribution from type II fibers at high powers. Finally, a statistical evaluation of the data suggests that if the two fiber types differ in their mechanical efficiency, the difference is no more than 12% during cycling at 1.5 Hz.

Methodological considerations of mechanical efficiency

Former studies addressing the efficiency during exercise have not standardized their conditions adequately, and that may have influenced their results. Therefore some methodological issues on establishing the efficiency are addressed. The efficiency has in this study been determined for each subject based on measurements of the O_2 uptake during 8–10 min of exercise at constant intensity since a steady state is usually reached within 8 min of exercise [1, 9, 23]. Exercise was done during conditions where anaerobic energy release is negligible [32]. Thus, the measured O_2 uptake reflects the total ATP-turnover rate. The efficiency was determined individually from at least nine and in average 19 values of the steady state O_2 uptake measured at a wide range of powers. The approach used is thus in line with recommendations for obtaining reliable relationships that suggest a minimum of eight measurements [31].

By carrying out the experiments along the principles outlined above, the statistical error in single determinations of delta efficiency was only 0.007 or less than 3% of the mean value of 0.26. By using a fixed *Y*-intercept the error was reduced further to less than 1%. The gross efficiency was determined from the established regression lines rather than from single measurements since that reduced errors in single determinations from 0.005 to < 0.002, that is from 2.5% to

0.8% of the mean value of 0.21. Thus, errors in single efficiencies were far less than those in other studies. Moreover, the errors were also much less than the between-subjects-variations. This means that it is not likely that analytical and statistical errors have masked a systematic effect and thus influenced conclusions drawn from the present data.

Other studies have used only one or a few measurements for establishing the relationship between exercise intensity and O_2 uptake [5, 8, 15], which makes their data less reliable. In some studies the measurements used cover a quite narrow range [8, 38], and that increased the imprecision in each delta efficiency determined.

There is a disproportionately high O_2 uptake at low exercise intensities that will introduce nonlinear effects at low powers (see Figures in Ref. [28, 31]), a phenomenon that may have a simple biomechanical explanation. Exercise at intensities below ≈ 1 W kg^{-1} was therefore avoided, and thus no essential nonlinear effects were seen (Figure 1). Another study did not avoid the problem of high O_2 uptake at low powers for the group with mainly type II fibers [38], and that may have influenced the conclusions drawn in that study.

The gross efficiency was taken from the same quite high power for all subjects. That is important as the following calculations show. Assume that the O_2-uptake (nO_2) rises linearly with power (P): $nO_2 = A + b\,P$ where A is the Y-intercept and b the slope. The gross efficiency is then $\eta_{gross} = P/nO_2$, and its inverse, a measure of the energetic cost of a standardized work or exercise intensity, is $(\eta_{gross})^{-1} = nO_2/P = (A + b\,P)/P = A/P + b$. Since all subjects were compared at the same power P, the inverse gross efficiency $(\eta_{gross})^{-1}$ is the slope b plus a nearly constant term A/P since the Y-intercept A did not vary much between subjects and P was fixed at 3 W kg^{-1}. If on the other hand P differs between subjects, then $(\eta_{gross})^{-1}$ and thus also η_{gross} will vary accordingly, resulting in higher apparent gross efficiencies the higher the power. Three studies that found a relationship between fiber type proportion and efficiency, did not standardize the experimental conditions sufficiently [8, 15, 38]. Bosco and coworker who found no relationship between fiber type proportion and efficiency, examined their subjects at the same power [5].

It could be argued that inadequately controlled experimental conditions should not introduce systematic effects. That is true only if the factors not controlled for are unrelated to fiber type proportion. The training state may for example correlate to fiber type proportion [7], and even a statistically nonsignificant correlation may introduce a systematic effect if it is large. In line with this, it is noteworthy that the variation in efficiency between subjects in other studies [8, 15] was 2–3 times larger than in the present one.

Three different measures of efficiency were used here. The delta efficiency using a fixed *Y*-intercept is regarded as the best measure. When adequately established, the *Y*-intercept does not seem to vary systematically between subjects but shows variations that seem random but that nevertheless affect the calculated delta efficiency. That possibly random effect is minimized when a fixed intercept is used. In addition, the approach using delta efficiency with a fixed *Y*-intercept showed very little statistical error in single determinations in this study.

Second-order curve fits and two-line fits were also examined here. If present at all, the second-order component was small. Moreover, the relationships found were unstable and numerically nonrobust. Thus, use of second-order fits seems unreliable in the analysis of relationships between O_2 uptake and exercise intensity. Likewise, two-line fits did not identify breakpoints and improve the relationships.

Effect of fiber type on efficiency

There was no effect of fiber type on efficiency in this study. An efficiency independent of fiber type working is supported by data from several other studies. During exercise at constant power lasting many minutes to more than an hour, there is a gradual recruitment of type II fibers by time in the quadriceps muscle [13, 14, 43, 44]. Despite this there is little change in the O_2 uptake [1, 9, 23, 44]. Moreover, as mentioned above, Bosco and coworkers who examined the efficiency for 32 subjects cycling at 1.0 Hz, found no correlation to the proportion of type I fibers in the knee extensor muscle [5]. Contrary to other studies showing an apparent effect of muscle fiber type, Bosco and coworkers standardized their experimental conditions. The authors suggested that their finding was a consequence of the pedalling frequency of 1.0 Hz chosen and that an effect might be seen at higher or lower frequencies. The present study carried out at 50% higher frequency, but there was still no effect of fiber type on efficiency.

The present results are at variance with other studies that suggested either that type II fibers work more efficiently than type I fibers do at high pedalling frequencies [38], or that type I fiber work more efficiently than type II fibers do [8, 15]. As pointed out above, there are several problems in the experimental design in these studies that may have influenced the results.

As a further analysis of the effect of fiber type on efficiency, relationships between O_2 uptake and power were determined at powers above and below the estimated recruitment threshold of type II fibers. The efficiency did not differ much between low and high powers. This analysis assumes that there is little activation of type II fibers at low powers, as suggested by measurements [43, 44] as well as semi-quanitative analyses [13, 14, 40] of changes in muscle glycogen concentration in single fibers of the knee extensor muscle. These conclusions may be challenged by data of Ivy and coworkers who measured concentrations of phosphocreatine, lactate, malate, glucose-6-phosphate, and ATP in single fibers of the knee extensor muscle during exercise [20]. Almost all fibers of both fiber types appeared active even at powers below 50% of the maximal O_2 uptake as judged from changes in the concentration of measured muscle metabolites. However, their system may be very sensitive and pick up even the slightest activation of type II fibers, too low to break down significant amounts of glycogen and contribute considerably to the work done. A synthesis and compromise of data of the studies mentioned above may suggest that at low powers mainly but not exclusively type I fibers work, while at higher powers both fiber types contribute considerably. This interpretation is in line with data on recruitment of single motoneurons showing that small motoneurons activating type I muscle fibers are usually but not always activated before larger neurons innervating type II fibers are [18, 37]. Thus, the analysis of recruitment threshold of type II fibers as suggested in figure 1 seems largely justified.

There was no significant correlation between the proportion of type IIB fibers and the two most robust efficiency measures used. If these fibers were recruited at low and moderate powers, this suggests that even type IIB fibers may work with an efficiency similar to that of type I fibers during cycling at 1.5 Hz. However, it may be that type IIB fibers are recruited only at quite high powers [43]. Therefore, no certain conclusion can be drawn on efficiency of type IIB fibers from the insignificant correlation found in this study. However, data of another study showed little increase in the O_2 uptake as type IIB fibers were involved towards the end of exercise [44]. This is compatible with the idea that also type IIB fibers work as efficiently as other muscle fibers do.

Theoretical considerations and muscle efficiency of in vitro studies
Muscles work by cross-bridge cycling [19], and one cross-bridge cycle appears to require one molecule of ATP irrespective of muscle fiber type. If so, one would not expect the efficiency to vary with fiber type. That conclusion may be too simplistic since other processes in the muscle like ion pumping require ATP. The Na, K-pump may require only $\leq 2\%$ of the total ATP-turnover during exercise [11, 30]. If so, possible differences between fiber types may not be of quantitative importance. Removal of calcium ions from cytosol to sarcoplasmic reticulum is another ion-pumping process that requires ATP. Effects of possible differences between fiber types concerning calcium pumping are more difficult to estimate.

In the present study energy release was taken from the measured O_2 uptake that rose with power. While working muscles use most of the O_2, some of the extra O_2 taken up during exercise is consumed by the heart and the ventilatory system. This means that the delta efficiency of ≈ 0.26 as calculated in the present study for the whole body is less than that for the working leg or muscles. Comparable measurements on single muscle should therefore give higher values for the efficiency since these measurements are not influenced by O_2 consumption of heart and respiratory muscles.

Some studies on the efficiency of rat muscles stimulated *in vitro* have suggested that muscle with mainly type I fibers are twice as efficient as those dominated by type II fibers [12, 16, 46]. The efficiency in those studies ranged between 0.07 and 0.18, roughly half the efficiency in the present experiments, which means that in these studies isolated muscles appeared to require roughly twice as much energy as the present subjects did to do a certain amount of work. The low efficiency in these studies suggests that extrapolating the results to exercising humans may be questioned.

More recent studies have used different stimulation protocols and found muscle efficiencies in the range 0.3–0.5 [2, 16]. The reported efficiency varies considerably between protocols used. In some experiments muscle with mainly type I fibers were more efficient than those with mainly type II fibers, while in other studies type II fibers appeared more efficient than type I fibers. Since the mechanical efficiency found depended on the protocol used, it is not known to what extent results from these studies can be extrapolated to exercising humans.

Further methodological considerations

The recruitment threshold of type II fibers was estimated using others data on the knee extensor muscle [43]. Other muscles work too during cycling, and these muscles may have different recruitment thresholds for type II fibers. The estimated thresholds (see arrowheads in Figure 1) should therefore be taken only as rough indicators of where recruitment of type II fibers begins. Since the proportion of type I fibers differed widely between the subjects, even these rough estimates may be of value. It should further be pointed out that the insignificant correlation between efficiency and fiber type is not affected by incorrect estimation of the recruitment threshold.

The experiments were carried out at a quite high pedalling frequency of 1.5 Hz, and most other studies have used lower frequencies. It could be that at the frequency used type II fibers are recruited even at low powers. However, the pattern of glycogen breakdown in single muscle fibers does not differ between frequencies of 0.5 and 2.0 Hz [14].

For each subject the proportion of each fiber type was established from biopsies taken from only one muscle. For each subject a minimum of 200 fibers were classified as type I or type II in each of at least four biopsies from the lateral portion of the knee extensor muscle (*m. vastus lateralis*). This gives a good estimate of the fiber type proportion in that muscle [4, 10, 26]. The knee extensor muscle is only one of several important muscles used during cycling. Information about the muscle fiber type proportion in other working muscles is therefore needed. That issue is addressed in the appendix where a statistical analysis on others data [21] shows that the fiber type proportion in one muscle, for example the knee extensor, provides important information about the proportion of fiber types in all working muscles when different persons are compared.

CONCLUSION

Data from the present study suggest that type II fibers work as efficiently as type I fibers do during cycling at a frequency of 1.5 Hz.

APPENDIX

Statistical analysis of fiber type proportions in 50 muscle sites

Background. In most muscle biopsy experiments, samples are taken from only one muscle, while many muscles are usually working during exercise, for example during cycling. Data relating physical performance to muscle fiber type proportions in one muscle have limited relevance unless data on fiber type proportions are relevant to all active muscles. This appendix shows that there is a close relationship between the proportions of type I fibers in different muscles when different subjects are compared.

Methods. Johnson and coworkers classified and reported fiber types in biopsies from fifty sites in altogether 36 muscles in six previously healthy men 17–30 yr old suffering from sudden deaths [21]. Their data are re-analysed here. Data of altogether 290 samples were reported (Table 2 in ref. [21]). Data on ten missing values have here been estimated according to Snedecor and Cochran [36]. A simple two-way analysis of variance (ANOVA) on these data has been carried out, using the following model:

$$p_{ij} = \mu + s_i + m_j + e_{ij} \qquad \text{(A1)}$$

μ is the mean proportion of type I fibers in all samples (grand mean); s_i, $i = 1, ..., 6$, denotes the six different *s*ubjects; m_j, $j = 1, ..., 50$, denotes the fifty different *m*uscles or muscle sites; e_{ij} is a normally distributed error term with expectation $E(e_{ij}) = 0$, and p_{ij} is the measured *p*roportion of type I fibers in the sample from subject s_i on muscle site m_j. The analysis of variance was carried out in SPSS version 15.0 using a model without interactions, and the corrections required to account for ten estimated values were calculated by hand. Further calculations were carried out in a spreadsheet. The relative error in estimated SDs from n measurements was taken as $(2n)^{-0.5}$.

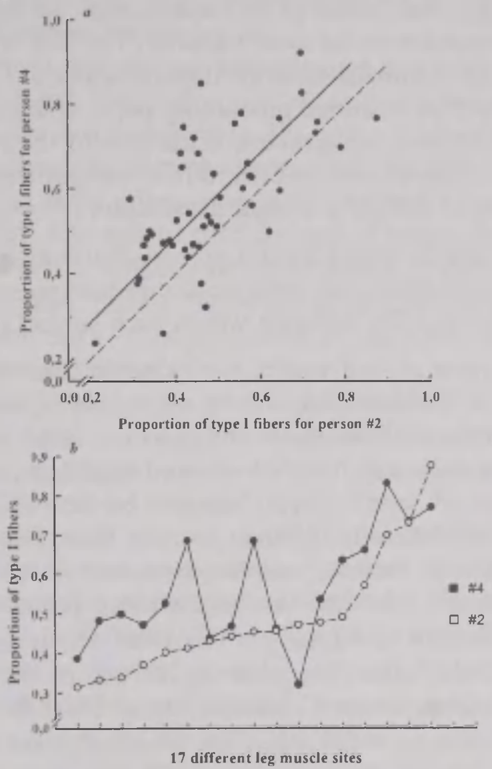


Figure 3. Biopsy data from Johnson and coworkers on proportion of type I fibers in different muscle sites [21]. Data from subjects #2 and #4 are used. Subject #2 had the second smallest and subject #4 the second largest proportions of type I fibers in the 17 leg muscle sites examined on six persons, and their data are thus used as maximum likelihood estimates of the 0.25 and 0.75 fractile in a human population. *a*, data on proportion of type I fibers in 49 muscle sites of person #4 versus person #2; data on *m. frontalis* were missing from person #2. The dashed line is the line of identity, while the solid line is a parallel line displaced 0.09, which is the difference between the mean proportion of type I fibers of 0.48 for person #2 and of 0.57 for person #4. *b*, biopsy data from 17 sites from nine hip, thigh, and calf muscles (person #2, open symbols and dashed curve; person #4 filled symbols and solid curve). The different sites are ranked in rising order of proportion of type I fibers for person #2. The mean proportion of type I fibers in these 17 muscle sites was 0.49 for person #2 (∘) and 0.56 for person #4 (•) and are shown to the right.

Model checking. The model (A1) assumes that the error terms are normally distributed with the same variance. The following three tests show that the data followed these assumptions closely: First, the residuals were plotted on a normal probability paper and appeared linear. Second, the skewness and (corrected) kurtosis of the residuals were 0.14 and 0.3, respectively, which differ insignificantly from the expected values of 0.0 for a normal distribution ($P = 0.3$). Third, the variance of a sample drawn from a normal distribution follows a χ^2 distribution. Accordingly, the variance within each muscle site (across the six subjects) and the variance within each subject (across the 50 muscle sites) were plotted versus a χ^2 distribution with the appropriate degrees of freedom (five and 49, respectively), and close linear relationships between the expected and observed values were found.

Results. The two-way ANOVA showed significant differences in the proportions of type I fibers between persons ($F_{5, 235} = 44.4$; $P < 0.001$) and between different muscle sites ($F_{49, 235} = 14.5$; $P < 0.001$), and the random variation term was 0.089 ± 0.004. For example, person #1 who had the largest mean proportion of type I fibers among the six men ($\bar{p}_{t\,I,\,\#1} = 0.66$) had relatively more type I fibers than all the other five men in 33 out of 50 muscle sites examined. Likewise, person #3 who had the smallest mean proportion of type I fibers ($\bar{p}_{t\,I,\,\#3} = 0.43$) had the smallest proportion of type I fibers among the six men in 25 of 50 muscle sites examined. Moreover, person #1's proportion of type I fibers was larger than that of person #3 in all 50 muscle sites examined.

Persons #1 and #3 were extremes within the sample of six men and thus not suited for describing typical cases. Persons #2 and #4 had the second smallest and second largest, respectively, proportion of type I fibers in a subsample of 17 leg muscle sites examined further below, and these two men were therefore chosen as (maximum likelihood) estimates of the 0.25 and 0.75 fractile (first and third quartile), respectively, in a human population of healthy young men. The proportion of type I fibers was larger for person #4 than for person #2 in 41 out of 49 muscle sites (Figure 3a; $P < 10^{-5}$ on a binomial test).

Johnson's data include a number of muscles probably little active during cycling and running. Their data from 17 leg muscle sites probably working during leg exercise were re-examined. Person #4's proportion of type I fibers was larger than for person #2 in 15 out of the 17 muscle sites ($P = 0.004$) despite the residual variation of 0.076 ± 0.006 in that subsample (Figure 3b).

The two-way analysis of variance did not allow analysis of possible interactions since there were no replications (only one value in each cell in the two-way layout). Thus, the observed residual variation is really a pooled effect of true residual variation plus a possible interactions. The latter effect is probably minimal. First, there is little reason to assume interactions here. Second, if interactions were significant, the observed residual variation would probably not appear normally distributed. Finally, the observed residual variation of ≈0.08 is similar to the error of measurement of the fiber type proportion based on one muscle biopsy [4, 10, 26].

Comparisons of with other studies. The standard deviation in proportion of type I fibers between persons within muscle sites averaged 0.11 in the data of Johnson and coworkers. That value is similar to the standard deviation of 0.13 reported by Coyle and coworkers for 19 well-trained cyclists [8] and to $s_{\text{type I}} = 0.13$ found in the present study too. Barstow and coworkers reported a standard deviation of 0.16 for their nine subjects [3], Pedersen and coworkers reported a standard deviation of 0.15 for their 12 subjects [33], while Simoneau and coworkers found a standard deviation of 0.14 for 50 subjects examined [35]. It should be noted that the observed standard deviation in each study is a combined effect of true differences between subjects and sampling errors. The latter term may vary between 0.03 and 0.08 [4, 10, 26].

The average proportion of type I fibers in the deep portion of *m. vastus lateralis* was 0.47 among the men studied by Johnson and coworkers [21]. That value does not differ much from the proportion of 0.55 among the 19 well-trained cyclists of Coyle and coworkers [8], of 0.47 for nine subjects examined by Barstow and coworkers [3], of 0.54 for 50 subjects examined by Simoneau and coworkers [35] and 0.50 among the 23 moderately trained young men in the present study. The value differs considerably from the mean proportion of 0.69 found on well-trained men by Pedersen and coworkers [33]. Finally, the proportion of type I fibers in seven different sites of the knee extensor muscle average 0.44 among the men studied by Johnson and coworkers. Thus, although they examined only six young men, it is conceivable that their data are quite typical for what is seen among healthy young men in a general population.

Conclusions. The fiber type proportion varies systematically between persons and muscles. The proportion in each subject's muscle can be described by a simple two-factor additive model (A1). This means that if two persons are examined and the proportion of type I fibers in one muscle differ by Δp between the two persons, (A1) suggests that the difference between the two persons in the proportion of type I fibers is Δp for all muscles, apart from the sampling error. Persons with a high proportion of type I fibers in the knee extensor muscle will thus most likely have a relative high proportion of type I fibers in all muscles.

ACKNOWLEDGEMENTS

I am grateful to Dr. Izumi Tabata and engineer Bjørg Ingrid Selberg who carried out the fiber typing.

REFERENCES

1. Bahr R., Opstad P. K., Medbø J. I., Sejersted O. M. (1991) Strenuous prolonged exercise elevates resting metabolic rate and causes reduced mechanical efficiency. Acta Physiol. Scand. 141: 555–563.
2. Barclay C. J. (1994) Efficiency of fast- and slow-twitch muscles of the mouse performing cyclic contractions. J. Exp. Biol. 193: 65–78.
3. Barstow T. J., Jones A. M., Nguyen P. H., Casaburi R. (2000) Influence of muscle fiber type and fitness on the oxygen uptake/power output slope during incremental exercise in humans. Exp. Physiol. 85: 109–116.
4. Blomstrand E., Ekblom B. (1982) The needle biopsy technique for fibre type determination in human skeletal muscle – a methodological study. Acta Physiol. Scand. 116: 437–442.
5. Bosco C., Komi P. V., Sinkkonen K. (1980) Mechanical power, net efficiency and muscle structure in male and female middle-distance runners. Scand. J. Sports Sci. 2: 47–51.
6. Box G. E. P., Hunter W. G., Hunter J. S. (1978) Statistics for Experimenters. An Introduction to Design, Data Analysis, and Model Building. John Wiley & Sons, New York. 453–462, ISBN 0-471-09315-7.
7. Coyle E. F., Feltner M. E., Kautz S. A., Hamilton M. T., Montain S. J., Baylor A. M., Abraham L. D., Petrek G. W. (1991) Physio-

logical and biomechanical factors associated with elite endurance cycling performance. Med. Sci. Sports Exerc. 23: 93–107.

8. Coyle E. F., Sidossis L. S., Horowitz J. F., Beltz J. D. (1992) Cycling efficiency is related to the percentage of type I muscle fibers. Med. Sci. Sports Exerc. 24: 782–788
9. Dick R. W., Cavanagh P. R. (1987) An explanation of the upward drift in oxygen uptake during prolonged submaximal downhill running. Med. Sci. Sports Exerc. 19: 310–317.
10. Elder G. C. B., Bradbury K., Roberts R. (1982) Variability of fiber type distribution within human muscles. J. Appl. Physiol. 53: 1473–1480.
11. Evertsen F., Medbø J. I., Jebens E., Nicolaysen K. (1997) Hard endurance-training increases Na^+–K^+ pump concentration in skeletal muscle of elite cross-country skiers. Am. J. Physiol. Regulatory Integrative Comp. Physiol. 272: R1417–R1424.
12. Gibbs C. L., Gibson R. (1972) Energy production of rat soleus muscle Am. J. Physiol. 223: 864–871.
13. Gollnick P., Armstrong R. B., Saubert C. W., Sembrowick C. L., Shepherd R. E., Saltin B. (1973) Glycogen depletion patterns in human skeletal muscle. Pflügers Arch. 344: 1–12.
14. Gollnick P., Piehl K., Saltin B. (1974) Selective glycogen depletion pattern in human muscle fibres after exercise of varying intensity and varying pedalling rates. J. Physiol. 241: 45–57.
15. Hansen E. A., Andersen J. L., Nielsen J. S., Sjøgaard G. (2002) Muscle fibre type, efficiency, and mechanical optima affect freely chosen pedal rate during cycling. Acta Physiol. Scand. 176: 185–194.
16. Heglund N. C., Cavagna G. A. (1987) Mechanical work, oxygen consumption, and efficiency in isolated frog and rat muscle. Am. J. Physiol. Cell Physiol. 253: C22–C29
17. Henneman E. (1957) Relationship between size of neurons and their susceptibility to discharge. Science 126 (3287): 1345–1347.
18. Henneman E., Somjen G., Carpenter D. O. (1965) Functional significance of cell size in spinal motoneurons. J. Neurophysiol 28: 560–580.
19. Huxley H. E. (1985) The crossbridge mechanism of muscular contraction and its implications. J. Exp. Biol. 115: 17–30.
20. Ivy J. L., Chi M. M.-Y., Hintz C. S., Sherman W. M., Helledall R. P., Lowry O. H. (1987) Progressive metabolic changes in individual human muscle fibers with increasing work rates. Am. J. Physiol. 252: C630–C639.

21. Johnson M. A., Polgard J., Weightman D., Appleton D. (1973) Data on the distribution of fibre types in thirty-six human muscles. An autopsy study. J. Neur. Sci. 18: 111–129.
22. Jones R. H., Molitoris B. A. (1984) A statistical method for determining the breakpoint of two lines. Anal. Biochem. 141: 287–290.
23. Kalis J. K., Freund B. J., Joyner M. J., Jilka S. M., Nittolo J., Wilmore J. H. (1988) Effect of ß-blockade on the drift in O_2 consumption during prolonged exercise. J. Appl. Physiol. 64: 753–758.
24. Krogh A. (1913) A bicycle ergometer and respiration apparatus for the experimental study of muscular work. Scand. Arch. Physiol. 30: 375–394.
25. Lentner C. (ed.) (1981) Units of Measurements, Body Fluids, Composition of the Body, Nutrition. Geigy Scientific Tables, Vol. 1. Ciba-Geigy Inc., Basel. 228–231.
26. Lexell J., Taylor C., Sjöström M. (1985) Analysis of sampling errors in biopsy techniques using data from whole muscle cross sections. J. Appl. Physiol. 59: 1228–1235.
27. Medbø J. I. (1990) Type I and type II fibres work with the same mechanical efficiency during bicycling. In: Muscle and Motility, vol 2. Maréchal G., Carraro U. (eds.). Proceedings of the 19th European Conference in Brussel. Intercept, Andover, Hampshire. 303–308.
28. Medbø J. I. (1996) Is the maximal accumulated oxygen deficit an adequate measure of the anaerobic capacity? Can. J. Appl. Physiol. 21: 370–383.
29. Medbø J. I. (2005) Examination of different ways to establish relationships between the O_2 demand and the exercise intensity. Acta Kinesiol. Univ. Tartuensis 10: 89–115.
30. Medbø J. I., Jebens E., Vikne H., Refsnes P. E., Gramvik P. (2001) Effect of strenuous strength training on the muscle Na-K pump concentration in skeletal muscle of well-trained men. Eur. J. Appl. Physiol. 84: 148–154.
31. Medbø J. I., Mohn A.-C., Tabata I., Bahr R., Vaage O., Sejersted O. M. (1988) Anaerobic capacity determined by the maximal accumulated O_2 deficit. J. Appl. Physiol. 64: 50–60.
32. Medbø J. I., Tabata I. (1989) Aerobic and anaerobic energy release and work during shortlasting, exhausting bicycle exercise. J. Appl. Physiol. 67: 1881–1886.
33. Pedersen P. K., Sørensen J. B., Jensen K., Johansen L., Levin K. (2002) Muscle fiber type distribution and nonlinear VO_2–power output relationship in cycling. Med. Sci. Sports Exerc. 34: 655–661.

34. Scholander P. F. (1947) Analyzer for accurate estimation of respiratory gases in one-half cubic centimetre sample. J. Biol. Chem. 167: 1–15.
35. Simoneau J.-A., Lortie G., Boulay M. R., Thibault M.-C., Bouchard C. (1986) Repeatability of fibre type and enzyme activity measurements in human skeletal muscle. Clin. Physiol. 6: 347–356.
36. Snedecor G. W., Cochran W. G. (1967) Statistical Methods. Iowa State Univ. Press, Ames, IA, USA. 317–321.
37. Somjen G., Carpenter D. O., Henneman E. (1965) Responses of motoneurons of different sizes to graded stimulation of supraspinal centers of the brain. J. Neurophysiol. 28: 958–965.
38. Suzuki Y. (1979) Mechanical efficiency of fast- and slow-twitch muscle fibers in man during cycling. J. Appl. Physiol. 47: 263–267.
39. Taylor H. L., Buskirk E., Henschel A. (1955) Maximal oxygen intake as an objective measure of cardio-respiratory performance. J. Appl. Physiol. 8: 73–80.
40. Thomson J. A., Green H., Houston M. E. (1979) Muscle glycogen depletion patterns in fast twitch fibre subgroups of man during submaximal and supramaximal exercise. Pflügers Arch. 379: 105–108.
41. Tissot J. (1904) Nouvelle methode de mesure et d'inscription du debit et des mouvements respiratoires de l'homme et des animaux. J. Physiol. Pathol. Gen. 6: 688–700.
42. Vaage O., Grønnerød O., Dahl H., Hermansen L. (1980) Subgrouping of skeletal muscle fibres in man. Acta Physiol. Scand. 108: 41A.
43. Vøllestad N. K., Blom P. (1985) Effect of varying exercise intensity on glycogen depletion in human muscle fibres. Acta Physiol. Scand. 125: 395–405.
44. Vøllestad N. K., Vaage O., Hermansen L. (1984) Muscle glycogen depletion patterns in type I and subgroups of type II fibres during prolonged severe exercise in man. Acta Physiol. Scand. 122: 433–441.
45. Weisberg S. (1985) Applied Linear Regression. John Wiley & Sons, New York. 279–281, ISBN 0-471-87957-6.
46. Wendt I. R., Gibbs C. L. (1973) Energy production of rat extensor digitorum longus muscle. Am. J. Physiol. 224: 1081–1086.

Correspondence to:
Jon Ingulf Medbø
National Institute of Occupational Health
Box 8149 Dep.
NO-0033 Oslo
Norway

HORMONAL ADAPTATIONS TO DIFFERENT TRAINING INTENSITIES DURING THE PREPARATION OF ELITE JUDOKAS FOR COMPETITION

D. Nemet[1,2], G. Lustig[2], H. Davidov[2], Y. Meckel[3], A. Eliakim[1,2,3]

[1] Child Health & Sport Center, Pediatric Department, Meir General Hospital, Sackler School of Medicine, Tel-Aviv University, Israel
[2] The Israeli Unit for Sport Excellence, Israeli Olympic Committee, Wingate Institute, Netanya, Israel
[3] Zinman College of Physical Education, Wingate Institute, Netanya, Israel

ABSTRACT

Many efforts are made to quantify objectively the balance between training load and the athlete's tolerance. The aim of the present study was to evaluate the balance between anabolic (i.e. testosterone and IGF-I) and catabolic (i.e. cortisol) hormones in elite judokas during their preparations (4 months) for the European championships. Five healthy elite Israeli judokas (four male, one female, age range 17–26 years) were tested at baseline, after two months of moderate training, after another one month of intense training, after one month of tapering down prior to the competition, and during the week after the championships. Hormonal level remained relatively unchanged during period of moderate training. Circulating levels of IGF-I and testosterone decreased and the cortisol/testosterone ratio increased during intense training. However, only the decrease in circulating IGF-I level reached statistical significance. Both levels of IGF-I and testosterone increased significantly, and the cortisol/testosterone ratio decreased significantly following tapering down, prior to the championships, compared to the levels during intense training. Changes in the balance of anabolic and catabolic hormones during the training season may help elite athletes and assist their coaches in their preparation for the competition.

Key words: athletes, anabolic, catabolic, IGF-I, Judo

INTRODUCTION

Training efficiency depends on the intensity, volume, duration, and frequency of training and on the athlete's ability to tolerate it. An imbalance between the training load and the individual's tolerance may lead to under or over-training. As a consequence, many efforts are made to quantify objectively the fine balance between training load and the athlete's tolerance. The endocrine system, by modulation of anabolic and catabolic processes, plays a major role in the physiological adaptation to exercise training [23]. For example, the change in the cortisol/testosterone ratio, as an indicator of the anabolic-catabolic balance, has been used with limited success to determine the physiological strain of training [8, 13]. In addition, changes in circulating components of the growth hormone (GH) → IGF-I (insulin-like growth factor-I) axis, a system of growth mediators that control somatic and tissue growth in many species [15], have been also used to quantify the effects of training [5].

Interestingly, very few studies examined the levels of these anabolic/catabolic hormones in elite athletes, during different training stages throughout the competitive season, in "a real life" condition. Therefore, the aim of the present study was to evaluate the balance between anabolic (i.e. testosterone and IGF-I) and catabolic (i.e. cortisol) hormones in elite judokas during their preparations for the European championships.

SUBJECTS AND METHODS

Five healthy elite Israeli judokas (four male, one female, age range 17–26 years) participated in the study. All the participants were members of the Israeli national judo team and prepared for the European championships. During the four months follow-up, there were differences in the training intensity. During the first two month training intensity was moderate and consisted of 14–16 hours of training per week (35% weights, 10% aerobic exercise, 35% judo fights and 20% judo techniques and tactics). This period was followed by one month of heavy and intense training (14–16 hours per week, 35% weight, 0% aerobic exercise, 50% judo fights and 15% judo techniques and tactics). Following the intense training the judokas experienced one month of tapering down prior to the competition. This period was characterized by reduced training volume and increase pure judo practices and tactics, and increased resting periods within each practice (12–14 hours per week, 30% weight, 10% aerobic exercise, 30% judo fights and 30% judo techniques and tactics). During this period and in particularly in the last week of this period the judokas tried deliberately to reduce their body weight in order to achieve their competition weight category.

Blood Sampling and analysis: Blood samples were collected at baseline (beginning of the season), and at the end of each training period [end of moderate training, end of intense training, end of tapering (two-three days before the competition) and during the week after the competition]. The tests were performed in the morning, following an overnight fast. Blood samples were immediately spun at 3000 rpm, at 4°C for 20 minutes. The serum was separated and stored at −80°C. All specimens were analyzed in the same batch by an experienced technician who was blinded to the order of samples.

Insulin-like Growth Factor-I: IGF-I was extracted from IGF-binding proteins (IGFBPs) by using the acid-ethanol extraction method. Serum IGF-I concentrations were determined by a two-site immunoradiometric assay by using the DSL-5600 Active kit (Diagnostic System Laboratories, Webster, TX). IGF-I intra-assay CV was 1.5–3.4%, and the inter-assay CV was 3.7–8.2%. Assay sensitivity was 0.8 ng/ml.

Cortisol: Serum cortisol levels were determined by a commercial RIA (Diagnostic Products Corporation, Los Angeles, CA). The intra and inter assay CV for this assay were 3.2% and 6.8% respectively.

Testosterone: Testosterone serum concentrations were determined by ELISA with the use of the DSL commercial kit (Diagnostic System Laboratories, Webster, TX). Intra-assay CV was 4.8–5.3%, inter-assay CV was 2.8–4.9%, and the sensitivity was 0.04 ng/ml.

STATISTICAL ANALYSES

Repeated measure ANOVA was used to assess the effect of exercise on IGF-I, testosterone and cortisol with time serving as the within group factor. Data are presented as mean ± SEM. Significance was taken at $p \leq 0.05$.

RESULTS

The circulating levels of IGF-I, testosterone, cortisol and the cortisol/testosterone ratio of the elite judokas at baseline, during periods of moderate and intense training, during tapering prior to the competition and after the competition are summarized in Table 1 and Figure 1. Three of the participants lost in the qualifying rounds of the championships. One judoka finished fifth and one judoka won the European championships. Body weight of the judokas remained stable throughout the training periods with a significant decrease of 2.4 ± 0.3 kg ($p < 0.01$) prior to the competition.

Hormonal level remained relatively unchanged during period of moderate training. Circulating levels of IGF-I and testosterone decreased and the cortisol/testosterone ratio increased during intense training. However only the decrease in circulating IGF-I level reached statistical significance. Both levels of IGF-I and testosterone increased significantly, and the cortisol/testosterone ratio decreased significantly prior to the championships compared to the levels during intense training. There was no significant change in cortisol levels during training, but, rather surprisingly, cortisol levels were significantly reduced after the competition.

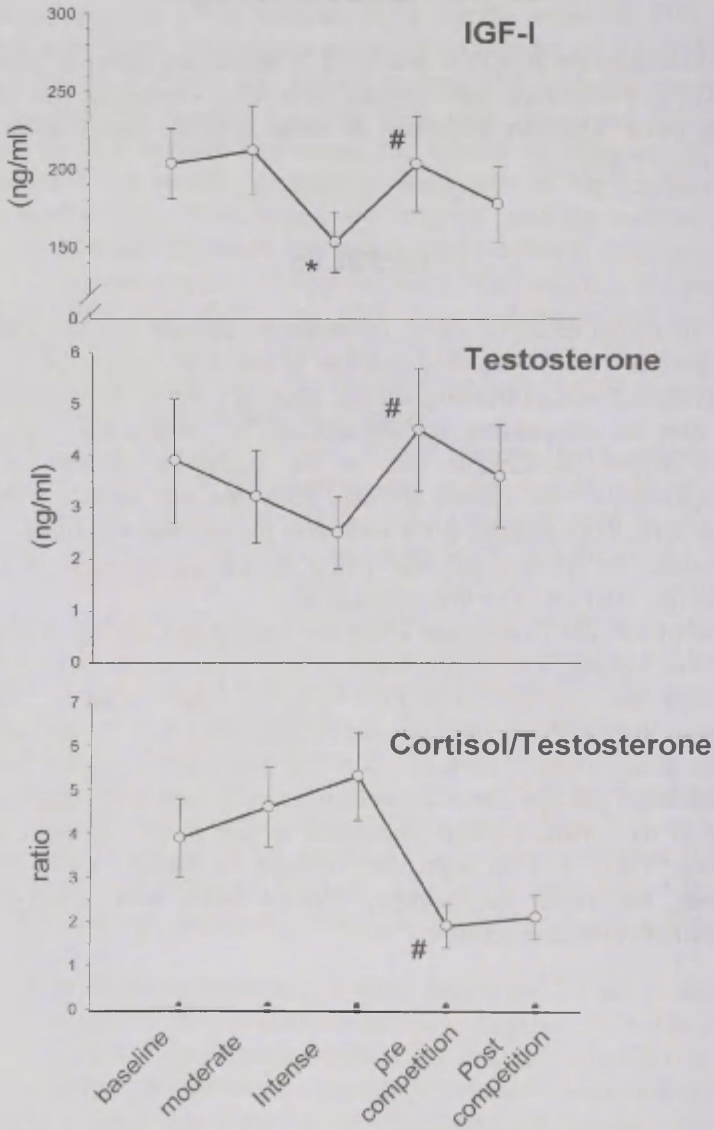


Figure 1. The anabolic/catabolic hormonal profile of elite judokas following different training intensities during the training season. * $p<0.05$ compared to baseline. # $p<0.05$ compared to intense training.

Table 1. The anabolic/catabolic hormonal profile of elite judokas during the training season.

	Baseline	Moderate	Intense	Pre competition	Post competition
IGF-I (ng/ml)	203.4±22.7	211.6±28.6	153.0±19.3*	202.8±30.3#	177.4±24.0
Testosterone (ng/ml)	3.9±1.2	3.2±0.9	2.5±0.7	4.5±1.2#	3.6±1.0
Cortisol (mcg/L)	17.7±1.4	18.9±2.6	16.6±2.1	11.3±2.3	9.6±1.9**
Cortisol/ Testosterone ratio	3.9±0/9	4.6±0.9	5.3±1.0	1.9±0.5#	2.1±0.5

* $p<0.05$ intense versus baseline
# $p<0.05$ pre competition versus intense training
** $p<0.05$ post competition versus baseline

DISCUSSION

We determined the effect of four months of training on circulating IGF-I, testosterone and cortisol level in elite judokas during their preparation for the European championships. Training consisted of two months of moderate training, followed by one month of intense training, and than one month of relative tapering prior to the championships. Both circulating IGF-I and testosterone level decreased during the period of intense training, but only the decrease in IGF-I reached statistical significance. Levels of IGF-I and testosterone increased significantly and returned to baseline levels (in the case of testosterone even slightly above baseline levels) during tapering.

We previously demonstrated that the initial response to 5 weeks of endurance-type exercise training was associated with a decrease in circulating IGF-I. These adjustments occurred despite training-induced increases in muscle mass, and improvement in fitness [6–8], suggesting different *local* tissue, and *systemic* responses to training. Moreover, these changes occurred even without evidence for negative energy balance or weight loss [19], and were associated with increases in inflammatory mediators [20]. These observations led to the speculation that the sudden imposition of endurance training program first leads to hormonal adaptations suggestive of a catabolic state, but at some point, an anabolic rebound occurs. Consistent with this hypothesis, longer periods of training (5m [12], and one year [24]) were indeed associated with increases in circulating GH and IGF-I levels.

Measurements of IGF-I levels can also assist the athlete and coach in the preparation for competition. We previously determined [4] the effect of four weeks of training on fitness, self-assessment physical conditioning scores and circulating IGF-I in elite professional handball players during their preparation for the junior world championships. Training consisted of two weeks of intense training followed by two weeks of relative tapering. Circulating IGF-I and physical conditioning scores decreased initially, and returned to baseline levels at the end of training. There was a significant positive correlation between the changes in circulating IGF-I and the physical conditioning scores. Consistent with our findings, a follow-up of IGF-I levels during the training season in elite adolescent wrestlers showed also a decrease in IGF-I level during periods of heavy training, and return to baseline during tapering down [21].

Hormonal changes during period of intense training are not unique only for IGF-I levels, and may occur in other anabolic hormones, such as testosterone [16, 22] and free testosterone [17], as well. The decreases in testosterone levels can occur following intense endurance and resistance training, and in particularly when training is associated with food restriction and negative energy balance (e.g. in judokas [1]).

Tapering down the training intensity prior to the competition is a well-known training methodology to help the athlete to achieve his best performance [22]. The results of the present study demonstrated that this strategy is indeed associated with parallel increases in both IGF-I and testosterone and with a decrease in the cortisol/testosterone ratio. Therefore, these measures may assist coaches and athletes in their training preparations. Interestingly, in type of sports that do not plan their training for a specific target, and train in the relative same intensity throughout the season (e.g. soccer), changes in IGF-I level were not found [19].

In optimal conditions, during the tapering of training intensity, IGF-I and testosterone level will increase above baseline levels and will be associated with improved performance. This did not occur in the present study. Since both IGF-I and testosterone can be affected by weight loss, it is possible that the deliberate decrease in body weight of the judokas prior to the championships prevented further increase in these anabolic hormones, and was associated "only" with a significant return to baseline values. Moreover, previous studies demonstrated training-associated negative correlation between circulating IGF-I and ghrelin in athletes [10], suggesting that these hormonal relationships can play a role in training-induced changes in body composition, in particularly in weight category sports.

As noted earlier, despite the decrease in circulating IGF-I [2, 3, 4, 6,] and testosterone [14] during intense training, fitness may still improve. This suggests that while changes in circulating IGF-I and testosterone are good markers of the general condition and energy balance of the athlete, they are not necessarily good predictors of the athlete's performance. Probably, it is the local muscle levels of these hormones, and their autocrine/paracrine secretion, that is more indicative of the muscle performance [7, 25]. Tapering of the training intensity, however, was found to be associated with increased IGF-I and testosterone level and with improvement of exercise performance of the athletes [9, 22].

It is still unknown what should be the permitted decrease of IGF-I and/or testosterone during periods of heavy training, or what should be the optimal increase of these substances during periods of tapering down and reduced training intensity. However, we believe that an inability to increase circulating IGF-I and/or testosterone levels before the target competition, should be an alarming sign for both the athlete and his/her coach that the athlete's general condition is not optimal. Collection of baseline and training- related hormonal changes, with a comparison to the hormonal response in previous seasons, and the knowledge and experience of the past success may prove to be of a very significant relevance as well.

The cortisol/testosterone ratio has been used frequently as an indicator of the anabolic-catabolic balance. In the present study there was a significant decrease in this ratio along with increase in IGF-I and testosterone during tapering prior to the competition. The changes in this ratio were mainly due to the changes in testosterone since, as was seen previously (e.g. 25), there were no significant changes in cortisol during the training. In addition, cortisol levels were probably more affected by the overall stress and not by training intensity, as suggested by the significantly lower levels after the European championships.

In summary, changes in the balance of anabolic and catabolic hormones during the training season may help elite athletes and their coaches in their preparation for the competition. Further studies are needed, however, to clarify the optimal hormonal response and its relationship with the athlete's performance.

REFERENCES

1. Degoutte F., Jouanel P., Begue R. J., Colombier M., Lac G., Pequignot J. M., Filaire E. (2006) Food restriction, performance, biochemical, psychological and endocrine changes in judo athletes. Int. J. Sport. Med. 27: 9–18.
2. Eliakim A., Brasel J. A., Mohan S., Barstow T. J., Berman N., Cooper D. M. (1996) Physical fitness, endurance training, and the GH-IGF-I system in adolescent females. J. Clin. Endocrinol. Metab. 81: 3986–3992.
3. Eliakim A., Brasel J. A., Mohan S., Wong W. L. T., Cooper D. M. (1998) Increased physical activity and the growth hormone-IGF-I axis in adolescent males. Am. J. Physiol. 275: R308–R314.
4. Eliakim A., Nemet D., Bar-Sela S., Higer Y., Falk B. (2002) Changes in circulating IGF-I and their correlation with self-assessment and fitness among elite athletes. Int. J. Sport. Med. 23: 600–603.
5. Eliakim A., Nemet D., Cooper D. M. (2005) Exercise, training and the GH → IGF-I axis. In: The endocrine system in sports and exercise. W. J. Kraemer, A. D. Rogol (eds). Oxford, UK: Blackwell publishing. 165–179.
6. Eliakim A., Scheett T. P., Newcomb R., Mohan S., Cooper D. M. (2001) Fitness, training, and the growth hormone-insulin-like growth factor-I axis in prepubertal girls. J. Clin. Endocrinol. Metab. 86: 2797–2802.
7. Greig C. A., Hameed M., Young A., Goldspink G., Noble B. (2006) Skeletal muscle IGF-I isoform expression in healthy women after isometric exercise. Growth. Horm. IGF. Res. 16: 373–376.
8. Hoffman J. R., Falk B., Radom Isaac S., Weinstein Y., Magazanik A., Wang Y., Yarom Y. (1997) The effect of environmental temperature on testosterone and cortisol responses to high intensity, intermittent exercise in humans. Eur. J. Appl. Physiol. 75: 83–87.
9. Izquerdo M., Ibanez J., Gonzalez-Badillo J. J., Ratamess N. A., Kraemer W. J., Hakkinen K., Bonnabau H., Granados C., French D. N., Gorostiaga E. M. (2007) Detraining and tapering effects on hormonal responses and strength performance. 21: 768–775.

10. Jürimäe J., Cicchella A., Jürimäe T., Lätt E., Haljaste K., Purge P., Hamra J., von Duvillard S. P. (2007) Regular physical activity influences plasma ghrelin consentrations in adolescent girls. Med. Sci. Sport. Exer. 39: 1736–1741.
11. Jürimäe J., Jürimäe T., Purge P. (2001) Plasma testosterone and cortisol responses to prolonged sculling in male competitive rowers. J. Sport Sci. 19: 893–898.
12. Koziris L. P., Hickson R. C., Chatterton R. T., Groseth R. T., Christie J. M., Goldflies D. G., Unterman T. G. (1999) Serum levels of total and free IGF-I and IGFBP-3 are increased and maintained in long term training. J. Appl. Physiol. 86: 1436–1442.
13. Kuoppasalmi K., Adlercreutz H. (1984) Interaction between catabolic and anabolic steroid hormones in muscular exercise. In: Exercise Endocrinology, K. Fotherby, S. B. Pal (eds). Berlin: de Gruyter. 65–98.
14. Kvorning T., Andersen M., Brixen K., Schjerling P., Suetta C., Madsen K. (2007) Supression of testosterone does not blunt mRNA expression of myoD, myogenin, IGF, myostatin or androgen receptor post strength training in humans. J. Physiol. 15: 579–593.
15. LeRoith D. (1991) Insulin-like growth factores: molecular and cellular aspects. CRC, Boca Raton, FL. 1–54.
16. Lucia A., Diaz B., Hoyos J., Fernandez C., Villa G., Bandres F., Chicharro J. L. (2001) Hormone level of world class cyclists during the tour de Spain stage race. Br. J. Sport. Med. 35: 424–430.
17. Mäestu J., Jürimäe J., Jürimäe T. (2005) Hormonal response to maximal rowing before and after increase in training volume in highly trained male rowers. J. Sport. Med. Phys. Fit. 45: 121–126.
18. Mejri S., Bchir F., Ben Rayana M.C., Ben Hamida J., Ben Slama C. (2005) Effect of training on GH and IGF-I responses to a submaximal exercise in football players. Eur. J. Appl. Physiol. 95: 496–503.
19. Nemet D., Connolly P. H., Pontello-Pescatello A. M., Rose-Gottron C., Larson J. K., Galassetti P., Cooper D. M. (2004) Negative energy balance plays a major role in the IGF-I response to exercise training. J. Appl. Physiol. 96: 276–282.
20. Nemet D., Oh Y., Kim H. S., Hill M., Cooper D. M. (2002) Effect of intense exercise on inflammatory cytokines and growth mediators in adolescent boys. Pediatrics 110: 681–689.
21. Nemet D., Pontello A. M., Rose-Gottron C., Cooper D. M. (2004) Cytokines and growth factors during and after a wrestling season in adolescent boys. Med. Sci. Sports. Exerc. 36: 794–800.

22. Steinacker J. M., Lormes W., Kellman M., Liu Y., Reissnecker S., Opitz-Gress A., Baller B., Gunther K., Petersen K. G., Kallus K. W., Lehmann M., Altenburg B. (2000) Training of junior rowers before world championships. Effects on performance, mood state and selected hormonal and metabolic responses. J. Sport. Med. Phys. Fit. 40: 327–335.
23. Urhausen A., Kindermann W. (2000) The endocrine system in overtraining. In: Sports Endocrinology, M. P. Warren, N. W. Constantini (eds). Totowa NJ: Humana Press. 347–370.
24. Weltman A., Weltman J. Y., Schurrer R., Evans W. S., Veldhuis J. D., Rogol A. D. (1992) Endurance training amplifies the pulsatile release of growth hormone: effects of training intensity. J. Appl. Physiol. 72: 2188–2196.
25. Zanconato S., Moromisato D. Y., Moromisato M. Y., Woods J., Brasel J. A., LeRoith D., Cooper D. M. (1994) Effects of training and growth hormone suppression on insulin-like growth factor-1 mRNA in young rats. J. Appl. Physiol. 76: 2204–2209.

Correspondence to:
Alon Eliakim
Child Health & Sports Center
Pediatric Department
Meir Medical Center
Kfar-Saba
Israel

Acta Kinesiologiae Universitatis Tartuensis. 2008, Vol. 13

COMPARATIVE ANALYSIS OF PHYSICAL DEVELOPMENT AND FUNCTIONAL CAPACITY OF DIFFERENT SPORTS ATHLETES DURING COMPETITION PERIOD

R. Paulauskas, E. Petkus, S. Sabaliauskas, R. Dadeliene, K. Milasius

Vilnius Pedagogical University, Vilnius, Lithuania

ABSTRACT

The aim of this study was to compare physical fitness of high performance canoeists, rowers, Greek-Roman style wrestlers, basketball players and skiers during their competition period. Indices of physical development, muscle and fat mass and their ratios were obtained. Single muscular contraction power (SMCP) and anaerobic alactic muscular power (AAMP) were also measured. The anaerobic glycolytic power (AGP) was estimated by ergometer. The Bosco methodology was used to estimate the activity of fast twitch fibres (FTF). The psychomotor response time (PRT) and movement frequency (MF) per 10 s were estimated and Roufier index (RI) was applied to measure functional capacity of circulatory and respiratory systems. The examination of athletes specialising in five different sports allowed for identification of the peculiarities of sports specialisation. The distinctive height, highest body weight and static hand power values characterised rowers and basketball players; while canoeists had the highest muscle mass. Only canoeists achieved high SMCP during the competition period. The SMCP of rowers and skiers was optimal, whereas the basketball players and wrestlers demonstrated an insufficient single muscular contraction power. The highest anaerobic alactic muscle power was observed in basketball players and canoeists, whereas in the muscles the basketball players and wrestlers the activity of FTF was insufficient. Though its parameters were approximate to endurance-trained rowers, they considerably fell behind those of canoeists. The functional capacity of circulatory and respiratory system of skiers was highest. The research revealed that the majority of indices of skiers and wrestlers' physical fitness were lowest among the other studied athletes. Such results reflect their limited potential to achieve high results in international competitions.

Key words: athletes of different sports, physical development, functional capacity.

INTRODUCTION

High performance level athletes differ from untrained individuals in the level of their physical development and functional capacity of their body. The central nervous system, muscles and cardiovascular system of athletes are adapted to intensive physical loads and are able to maintain high performance for a long period [2, 20, 24]. In a number of sports the height gives a certain advantage: when actions require motion amplitude (rowing) or occur at a height (basketball). However, athletes from a big variety of sports, whose height and muscle mass do not differ considerably, are still distinguished by various physical qualities and energy processes in the muscles that are typical of the sports they are in [1, 11, 12, 21]. During the process of young athletes' selection and developing their physical qualities later, it is important to be aware of the fact that sports results are determined by a large number of internal and external factors. Internal factors include genotypic adaptation features of an individual, which determine his/her functional abilities, though they may vary under the influence of specific external factors (physical loads). Purposive and specialised sports education and development highlights the prevailing physical qualities and increase organism powers [4, 7]. The science of sports gains an interest in evaluation and comparison of functional powers of athletes from different sports during the competition period.

The aim of the study was to compare physical and functional powers of high performance canoeists, rowers, Greek-Roman style wrestlers, basketball players and skiers during the competition period.

MATERIALS AND METHODS

The subjects were members of Lithuanian Olympic team: 8 canoeists, 4 rowers, 6 wrestlers of heavier weight classes, 9 skiers and 10 basketball players from a team playing in the Lithuanian Basketball League. All the athletes were investigated during their competition period.

Physical development, muscle and fat mass and their ratio were estimated ([16]). Single muscular contraction power (SMCP) [5] and anaerobic alactic muscular power (AAMP) were measured [14]. The anaerobic glycolytic power (AGP) of basketball players, wresters and skiers was estimated applying veloergometer [22]. Having modified this test, we measured AGP of rowers using ergometer and that of canoeists applying canoe-rowing ergometer. The Bosco methodology was employed to estimate the activity of fast twitch (FT) fibres [5]. The psychomotor response time (PRT) and movement frequency (MF) per 10 s were estimated and Roufier index (RI) was applied measuring functional capacity of circulatory and respiratory systems [25].

The results were statistically processed calculating the arithmetic mean value ($\overline{X}$), representative response error ($S\overline{x}$) and the reliability of difference in arithmetic means (p). A level of pL 0.05 indicated statistical significance.

RESULTS

The physical development indices of Lithuanian athletes from different sports are specific. No difference was observed in the height of basketball players and rowers, but it was approximately 14 cm larger ($p < 0.05$) than that of canoeists, wrestlers and skiers (Table 1). The difference in athletes' height had a direct influence on differences in body weight parameters: basketball players weigh 12.12 kg ($p < 0.05$) more than canoeists and they weigh 22.41 kg ($p < 0.05$) more than skiers. However, the wrestlers and canoeists are heavier than the skiers by 8–10 kg ($p < 0.05$) on the average. The highest ratio of muscle and fat was observed among canoeists (7.02) and the lowest one (4.50 ($p < 0.05$)) was identified among wrestlers. Differences in the indices of lung volume (LV) among all the athletes studied were statistically unreliable ($p > 0.05$). The LV of the rowers was bigger by 20% compared to the other athletes in the research sample ($p < 0.05$).

The hand power of the basketball players was strongest: the power value of their right hand was 10% bigger and the power value of their left hand was 12% bigger than those of canoeists and respectively 17% ($p < 0.05$) and 16% ($p < 0.05$) higher compared to that of the wrestlers. The weakest hand power was identified in the group of skiers.

The analysis of indices of muscle work of different length and their functional capacity highlighted exceptional features of special training of athletes from various sports. The highest single muscular contraction power was characteristic of canoeists (30.10 W/kg), whereas the lowest SMCP value was identified among the rowers, which amounted to 26.18 W/kg (Table 2). The difference in this indicator of both athletes' groups equals to 13 per cent ($p > 0.05$). Stronger SMCP of the canoeists is determined by their shorter take-off length: 182.44 ms. The jump height of basketball players was considerably bigger compared to the other athletes (16 per cent higher than the jump of the canoeist ($p < 0.05$) and 25 per cent higher than that of the skiers ($p < 0.05$). However, due to the long take-off, the basketball players' SMCP reaches only 28.04 W/kg. Having compared the indices of basketball players with those of other athletes in the research, we may conclude that the relative SMCP of the basketball players is approximate to the parameters of endurance-training rowers and skiers.

The highest anaerobic alactic muscular power (AAMP) was achieved by the basketball players and its value was approximately 10% ($p < 0.05$) bigger than that of the rowers and 7 % bigger ($p < 0.05$) compared to the AAMP of the skiers. High AAMP is also characteristic of canoeist: this indicator is 8% ($p < 0.05$) bigger than that of the rowers and 6% ($p < 0.05$) bigger compared to the skiers. The absolute AAMP of the basketball players is considerably higher in comparison to the skiers (a difference of 28% ($p < 0.05$).

Differently from the indicators of SMCP and AAMP, the strongest anaerobic glycolytic power was identified in rowers. This indicator amounts to 624.67 W and is 34% ($p < 0.05$) higher compared to the AGP of the wrestlers. High AGP is also characteristic for canoeists and it is 12% higher compared to that of the skiers and 8 per cent bigger in comparison to the basketball players. The analysis of the relative AGP revealed that the rowers' AGP value is highest: 6.93 W/kg.

Table 1. Indices of physical development of athletes from different sports during competition period($\overline{X} \pm S\overline{x}$)

INDICES	I Canoeists n=8	II Wrestlers n=6	III Basketball players n=10	IV Rowers n=4	V Skiers n=9
Body height, cm	182.69±1.98 I – V	180.42±3.15 II–V, II–III	194.90±1.72 III–I	195.17±3.44 IV–V	180.3±2.24 III–V
Body mass, kg	82.59±1.83 I–III, I–V	83.42±8.12 II–III, II–V	94.71±2.25	90.17±1.86 V–IV	72.30±1.47
BMI	24.38±0.32	25.72±1.68	24.90±0.64	23.67±0.88	22.55±0.53
Strength of right hand, kg	59±2.29	54.50±3.54 II–III	65.8±3.04	63±3.21	53.09±2.8
Strength of left hand, kg	54.5±1.95	51.17±3.16 II–III	61.60±2.75	56±2.31	49±1.68
LV, 1	5.94±0.21 I–V	5.2±0.37 II–V	5.97±0.13 III–V	6.87±0.23	5.41±0.14
Muscle mass, kg	45.03±1.25 I–V	44.60±3.77	50.22±0.89	50.57±1.55 V–IV	38.68±1.2
Fat mass, kg	6.73±0.62	10.57±1.71	8.49±1.11	8.71±0.95	7.04±0.51
MFMI	7.02±0.5 I–II	4.5±0.42	6.94±0.98	5.97±0.77	5.82±0.49

Note: $p<0.05$

Table 2. Indices of muscular power, psychomotor functions and circulatory and respiratory systems functions of athletes from different sports during competition period (X±Sx)

INDICES	I Canoeists n=8	II Wrestlers n=6	III Basketball players N=10	IV Rowers n=4	V Skiers n=9
Jump height, cm	55.75±2.85 I–III	54.33±1.09 II–III	66.18±1.86	55.33±4.1 III–V	48.91±2.43
Take-off time, ms	182.44±5.9 I–III	215.18±39.8	235.73±5.96 III–IV	211.9±19.65	182.52±10.4 III–V
SMCP, W/kg	30.10±2.11	25.29±1.62	28.04±0.90	25.69±0.84	26.18±1.23
SMCP, W	2485±239.8	2099±291.3	2660±311.7 III–V	2340±196.4	1879±319.8
AAMP, W/kg	17.06±0.41 I–II	16.27±0.20 II–III	17.25±0.32 III–V	15.59±0.11 V–IV	15.98±0.23 V–I
AAMP, W	1411±128.1	1352±111.3	1615±196.6 III–V	1404±101.1	1152±203.11 V–I
AGP, W/kg	6.18±0.59	4.92±0.45	4.98±0.56	6.93±0.69	6.23±0.55
AGP, W	513±35.74	408.87±8.7 II–IV	473.2±9.56 III–V	624.67±22.62 IV–V	449.40±16.2
Activity of FTF, %	52.14±2.81 I–III	42.17±3.4 II–I	41.18±2.51	43.33±1.45 V–I	–

	I	II	III	IV	V
INDICES	Canoeists	Wrestlers	Basketball players	Rowers	Skiers
	n=8	n=6	N=10	n=4	n=9
PRT, ms	189.75±8.17 I–V	196.67±6.15	188.82±2.81 III–V	210±3.58	191.27±6.24
MF, t/10 s	75+2.48	73.5+3.28	78.55±1.35	74±1.73	78.27±1.7
HR at rest, b/min	68.3±3.09	59.33±3.37 II–IV	62.82±1.99 III–IV	58±2.0	56.22±1.75
HR after standard load, b/min	120.16±3.74 IV–I	116.5±1.96	121±4.09 III–IV,III–V	105.33±2.67 V–I	122.22±2.42
HR after 1 min rest, b/min	79.33±1.61 I–IV	68.00±3.43	73.09±2.7	66.65±2.67 V–I	60.44±1.69 V–I
RI	4.73±0.53 I–IV	2.4±1.08	3.38±0.52 III–IV	3.53±0.66 IV–V	1.87±0.47 I–V

Note: $p<0.05$

The highest activity of fast twitch fibres (FTF) was identified in the muscles of the canoeists (52.0 %), whereas the lowest FTF value was observed among the basketball players and it amounted to 41.18% ($p < 0.05$). The most approximate parameters of twitch fibre activity are in the group of the basketball players, wrestlers and rowers: there is only a 5 % difference among them.

Well-developed balance abilities of CNS and fastest psychomotor response time were characteristic of the basketball players. The worst results of movement frequency (MF) and psychomotor response time (PRT) were achieved in the group of rowers.

The skiers' resting heart rate (HR) was only 56.2 b/min, whereas that of the canoeists amounted to 68.3 b/min ($p < 0.05$). The skiers demonstrated the lowest HR response to standard physical load and increased only to 105.33 b/min, the heart rate of the basketball players reached the average of 121 b/min, and that of the canoeists – 120.16 b/min. The best recovery response (after 1 min recovery) was identified in the group of skiers with the heart rate decreased to 60.44 b/min, and the canoeists demonstrated the longest recovery with the heart rate of 79.33 b/min ($p < 0.05$) after 1 min recovery. The skiers' Roufier index (RI) was the best and equalled to 1.87, whereas the worst index value was observed in the group of canoeists and it amounted to 4.73.

DISCUSSION

The competition activity of the athletes in the research sample is diverse: components of acyclic activity prevail in the actions of basketball players and wrestlers, when situation undergoes constant changes and movement is characterised through moments of shifting muscle power and complicated manifestations of psychomotor response. On the other hand, rowers, canoeists and skiers are involved in cyclic motion activity. Depending on the event, mixed anaerobic alactic, glycolytic energy generation reactions dominate and anaerobic capacity and endurance play the key role [8, 13, 21]. Our study revealed that the basketball players exceeded the other athletes in their height and body weight values. These indices of their physical development were higher compared to those of the wrestlers. The indices of basketball players' jump height and their relative anaerobic alactic muscle power were considerably higher compared to the athletes from other sports. Thus, it can be concluded that single and repetitive jumps, short spurts of acceleration activate anaerobic alactic energy generation reactions and develop single muscular contraction power.

The earlier researches have proved that higher height index and longer limbs give advantage while competing not only to basketball players but also to rowers [9, 17]. It can be concluded that the height of the rowers was significantly higher compared to that of wrestlers, canoeists and skiers but it did not statistically differ from the height index of basketball players.

A number of the authors [10, 15, 23] stated that special fitness of wrestlers is determined by their high anaerobic capacity. However, our research revealed that the relative indices of wrestlers AAMP and AGP were among the lowest in the sample.

Our results shows that single muscular contraction power did not have any substantial differences among separate groups of athletes. Though the basketball players jumped higher than the skiers, their single muscular contraction power was considerably weaker. This may be explained by the fact that basketball players and wrestlers' development of circulatory and respiratory system could have had a negative effect on single muscular contraction power [6, 18, 15]. No difference was observed in other forms of speed manifestation, i.e. psychomotor response time and movement frequency. Psychomotor response time is of extreme importance to basketball players but the PRS of the basketball players in the research was better only compared to that of the skiers. This proves that high performance basketball players failed to develop physical velocity qualities and separate forms of its manifestation to an appropriate level.

The highest activity of FTF among the athletes in the research was established in the group of canoeists (52.14%). Bergh et al. [3] stated that the FTF activity of Swedish National Team canoeists ranged from 29 to 53%. The muscle mass of the canoeists made up to 48% of the total body weight. A correlation was established between muscle mass and 200-meter distance time ($r = 0.66$) and the mass of special muscles and their power is of high importance for the results of 200-meter and 500-meter distances, whereas anaerobic capacity has a key relevance to the results of 1000-meter distance.

The heart rate at rest was highest in the group of skiers and amounted to 56.22 ± 1.75 b/min. The heart rate of an untrained individual is equal to 75–85 b/min, whereas the heart rate of a well fit skier may amount to 40 and sometimes even to 30 b/min [19].

The research results revealed that significant differences in qualities of physical development and physical fitness were not identified with an exception of the height and body weight parameters. This could have been conditioned by application of too low specific physical load and too intensive load in the sphere of general physical training.

CONCLUSIONS

1. The examination of athletes specialising in five different sports allowed for identification of the peculiarities of sports specialisation. The distinctive height, highest body weight and static hand power values were characteristic of rowers and basketball players; however, the canoeists' index of muscle mass was highest in the sample.
2. Only canoes achieved high SMCP during the competition period. The SMCP of the rowers and skiers was optimal, whereas the basketball players and wrestlers demonstrated an insufficient single muscular contraction power. The highest anaerobic alactic muscle power was observed in the muscles of basketball players and canoeists.
3. The activity of fast twitch muscles was insufficient in the group of both the basketball players and the wrestlers. It was approximate to endurance-training rowers but was considerably lower than the activity of canoeists' FTF.
4. The research revealed that the majority of indices of skiers' physical fitness were lowest among the athletes in the research. Such results reflect their limited potential to achieve high results in the international competitions.

REFERENCES

1. Abe T., Kojima K., Karns C. (2003) Whole body muscle hypertrophy from resistance training: distribution and total mass. Brit. J. Sports Med. 37: 543–545.
2. Astrand P. O., Rodahl K. (1986) Textbook of Work Physiology (2nd ed.). New York: Mc Graw-Hill. 669 p.

3. Bergh U., Thorstenssen A., Sjödin B., Hulten B., Pichl K., Karlson J. (1978) Maximal oxygen uptake and muscle fiber types in trained and untrained humans. Med. Sci. Sport Exerc. 10: 151–154.
4. Bangsbo J., Gollnick P., Kiens B., Mizuno M., Saltin B. (1990) Anaerobic energy production and O_2 deficit debit relationship during exhaustive exercise in humans. J. Physiol. 422: 539–559.
5. Bosco C., Komi P., Tihany J., Fekete C., Apor P. (1983) Mechanical power test and fibre composition of human leg extensor muscles. Eur. J. Appl. Physiol. 51: 129–135.
6. Coen B., Urhausen A., Kindermann W. (2003) Sport specific performance diagnosis in rowing: an incremental graded exercise test in coxless pairs. Int. J. Sports Med. 24: 428–432.
7. Cvetkovic C., Maric J., Marelic N. (2005) Technical efficiency of wrestlers in relation to some anthropometric and motor variables. Kinesiology, 37: 74–83.
8. Foster C., Brackenbury C., Moore M., Snyder A. (1996) System of sports specific performance diagnosis and monitoring of training in endurance sports and ball games in the United States. Deutche Zeitschr. Sportmed. 45: 190–195.
9. Hahn A. G. (1990) Identification and selection of talent in Australian rowing. Excel. 6: 5–11.
10. Yoon J. (2002) Physiological profiles of elite senior wrestlers. Sports Med. 32: 225–233.
11. Jagiello W., Tkaczuk W. (2005) Physical work capacity of young Greco-roman wrestlers on the background of their somatic development. Ugdymas, kūno kultūra, sportas, 3: 9–16.
12. Kais K., Raudsepp L. (2005). Intensity and direction of competitive state anxiety self – confidence and athletic performance. Kinesiology, 37: 13–20.
13. Mäestu J., Jürimäe J., Jürimäe T. (2005) Monitoring of performance and training in rowing. Sports Med. 37: 597–617.
14. Margaria R., Aghemo P., Rovelli E. (1966) Measurement of muscular power (anaerobic) in man. J. Appl. Physiol. 21: 1662–1664.
15. Milašius K., Tubelis L., Skernevičius J. (2006) Physical load and physical functional capacity in Greek-Roman wrestlers over the four-year Olympic cycle. Acta Kinesiol. Universit. Tartuensis, 11: 40–52.
16. Mohr M., Johnsen D. (1972) Tables for evaluation of body weight of adult men and women by their optimal weight (German). Zeitschrift für Artztliche Forbildung (Jena), 66: 1052–1064.
17. Palm R., Jürimäe J., Mäestu J. (2005) The validity of physiological variables to assess training intensity in rowers. Acta Kinesiol. Universit. Tartuensis, 10: 116–124.

18. Roth V., Hasart E., Wolf W. (1983) Untersuchungen zur dynamic der energiebereitstullung wahrend maximal mittelzeitausdauer belastung. Med. Sport, 23: 107–114.
19. Skernevičius J., Raslanas A., Dadelienė R. (2004) Sporto mokslo tyrimų metodologija. – V.: LSIC, – 220 p.
20. Shephard R. (1998) Science and medicine of rowing: a review. J. Sports Sci. 16: 603–620.
21. Steinacker J. (1993) Physiological aspects of rowing. Int J. Sport Med. 1: 3–10.
22. Szögy A., Cherebetin G. (1979) Minuten test auf dem fahrradergometer zur testimung der anaeroben capacitat. Eur. J. Appl. Physiol. 33: 171–176.
23. Turman P. D. (2003) The influence of coach experience on high school wrestlers preferences of coaching behaviour across season. J. Sport Behav. 52: 73–89.
24. Wilmore J. H. Costill D.L. (1994) Physiology of sport and exercise – Champaign Human Kinetics, 549 p.
25. Шеррер Ж. (1973). Физиология труда (эргономия). Москва, 223 с.

Correspondence to:
Rutenis Paulauskas
Studentų 39, LT-2034, Vilnius
Lithuania

BODY BUILD OF ELITE JUNIOR TAEKWONDO ATHLETES

W. Pieter

Department of Physical Education,
University of Asia and the Pacific, Pasig City, Philippines

ABSTRACT

The purpose of this study was to assess and compare the somatotype of elite junior taekwondo athletes. Subjects (9 boys, 15.44 ± 1.21 years, 165.94 ± 12.82 cm, 53.82 ± 13.41 kg, and 9 girls, 15.05 ± 1.30 years, 160.82 ± 10.46 cm, 50.58 ± 10.41 kg) were members of the US national junior taekwondo team. The Heath-Carter somatotype method was used to assess body build of the athletes. To determine the difference between boys and girls in somatotype, a 1-way Anova was used. The global somatotype analysis revealed no difference in somatotype attitudinal mean between boys and girls ($p = 0.411$, $eta^2 = 0.043$) or SAD ($p = 0.215$, $eta^2 = 0.094$). There was a small difference in endomorphy between boys and girls ($p = 0.053$, $eta^2 = 0.214$). Physique may be used as one of the selection criteria to detect and develop talent in taekwondo.

Key words: body, build, taekwondo

INTRODUCTION

Physical characteristics are believed to contribute to sports performance. For instance, elite female volleyball players were found to be taller than their colleagues in basketball and handball, with the least amount of body fat and a balanced mesomorphic body build [2]. Sexual dimorphism in somatotype was found in elite volleyball players by Gualdi-Russo and Zaccagni [13], while Wassmer and Mookerjee [26] reported more fat in elite female field hockey goalkeepers. However, there were no differences between playing positions in height, lower limb length, grip strength, agility and other motor abilities.

Anthropometric studies on combat sports are scarce. Katic [14] found adult elite karate athletes (karateka) to be predominantly characterized by a mesomorphic physique and transverse skeletal dimensionality. Fritzsche and Raschke [12] reported German adult male elite karateka to have a Heath-Carter somatotype of 2.0-3.7-2.7 and their female counterparts, of 3.4-2.4-2.4.

Few studies are available on the somatotypes of taekwondo athletes (taekwondo-in). For instance, American elite adult taekwondo-in were reported to have a somatotype of 1.65-4.53-3.59 (men) and 2.08-3.23-3.98 (women) [25]. Pieter [19] revealed similar physiques for elite taekwondo-in: 1.74-4.68-3.02 (men) and 2.47-3.08-3.47 (women).

Adolescent taekwondo-in were investigated by Pieter [19], who reported a somatotype of 2.02-3.96-4.26 for boys and of 2.78-3.26-3.83 for girls. In a more recent study, Pieter [20] revealed girls to score higher in endomorphy (3.2 vs. 2.3), while the boys were more mesomorphic (4.2 vs. 3.4). There was no difference in ectomorphy: 3.5 and 3.1 for the boys and girls, respectively. In view of the lack of research on young taekwondo-in, the purpose of the current investigation was to describe and compare the somatotypes of male and female junior elite taekwondo athletes.

METHODS

Subjects (9 boys, 15.44 ± 1.21 years, 165.94 ± 12.82 cm, 53.82 ± 13.41 kg, and 9 girls, 15.05 ± 1.30 years, 160.82 ± 10.46 cm, 50.58 ± 10.41 kg) were members of the US national junior taekwondo team. Table 1 displays the taekwondo training details of the athletes.

Table 1. Means and standard deviations of training details of elite junior taekwondo-in

	Boys	Girls
Taekwondo experience (years)	6.80 ± 2.94	5.29 ± 1.13
Training days/week	4.78 ± 1.30	4.89 ± 0.78
Training times/day	1.67 ± 0.71	1.33 ± 0.71
Hours/session	2.00 ± 0.66	2.17 ± 1.30

Height was measured by means of a wall-mounted wooden stadiometer to the nearest 1 cm and an electronic weighing scale was used to assess body mass to the nearest 0.5 kg. Skinfold thicknesses were taken at the following sites with a Lange caliper: triceps, subscapular, supraspinale, and medial calf. In addition, biepicondylar widths of the humerus and femur were taken as well as the girths of the flexed and tensed upper arm and calf. The median was used for statistical analysis if the measurements had to be taken three times, while the mean was utilized if the first two measurements were within the acceptable range [22]. The Heath-Carter method was used to estimate somatotype [7].

To determine the difference between boys and girls in somatotype, a 1-way Anova was used. The level of significance was set to 0.05. It was decided not to adjust the type 1 error for multiple comparisons, because the interest was in the comparisonwise error rate as the data were generated through actual observations. The objective was to unearth any possible leads regarding the relationship between the independent and dependent variables [3, 23].

RESULTS

There were no differences between boys and girls in age ($p = 0.512$, $eta^2 = 0.027$), height ($p = 0.367$, $eta^2 = 0.051$) and weight ($p = 0.574$, $eta^2 = 0.020$). Table 2 shows the descriptive statistics of the somatotypes of the junior taekwondo-in. The global somatotype analysis revealed no difference in SAM between boys and girls ($p = 0.411$, $eta^2 = 0.043$) or SDM ($p = 0.215$, $eta^2 = 0.094$).

Table 2. Means and standard deviations of somatotypes in elite junior taekwondo-in

	Boys	Girls
Endomorphy	2.19 ± 0.70	2.88 ± 0.69
Mesomorphy	3.96 ± 0.82	3.24 ± 1.03
Ectomorphy	3.83 ± 0.94	3.41 ± 1.01
SAM	1.19 ± 0.68	1.43 ± 0.50
SDM	2.80 ± 1.66	3.81 ± 1.64

There was a small difference in endomorphy between boys and girls ($p = 0.053$, $eta^2 = 0.214$). No differences were found in mesomorphy ($p = 0.124$, $eta^2 = 0.141$) and ectomorphy ($p = 0.373$, $eta^2 = 0.050$).

Figure 1 depicts the somatoplots of both boy and girl taekwondo-in. There was a 33% overlap of girls with boys.

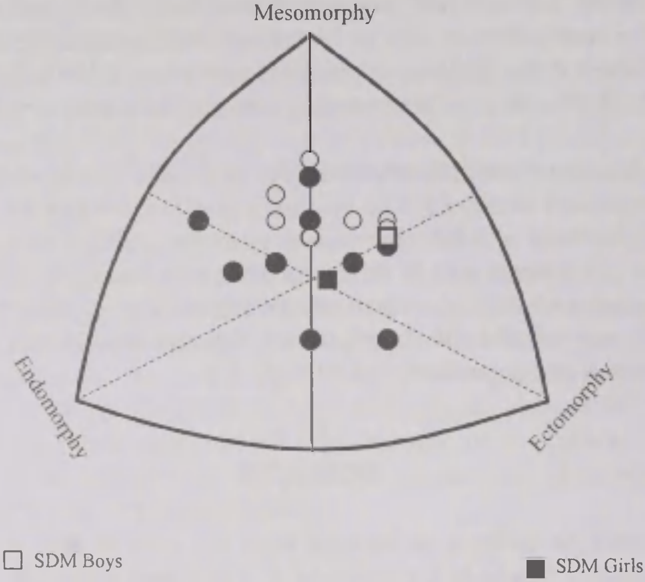


Figure 1. Somatoplots of boy and girl taekwondo-in

DISCUSSION

Table 3 displays comparative data on somatotypes of taekwondo-in and karateka. The physique of the current group is comparable to that of other American elite junior taekwondo athletes [19, 20]. Although there are sports-specific differences between karate and taekwondo in terms of their energy requirements [4, 5, 6], the physiques of the junior taekwondo-in are remarkably similar compared to those of adult karateka. The young male and female taekwondo-in are more ectomorphic, while the adult female karateka are more endomorphic than their young counterparts in taekwondo, which is in line with growth and development expectations [7, 16].

Table 3. Comparative somatotypes of taekwondo-in and karateka

Sport/Study	Males	Females
Taekwondo – Juniors		
This study	2.19-3.96-3.83	2.88-3.24-3.41
Pieter [20]	2.3-4.2-3.5	3.2-3.4-3.1
Pieter [19]	2.02-3.96-4.26	2.78-3.26-3.83
Taekwondo – Seniors		
Olds & Kang [18] (club)	2.5-4.9-2.7	--
Olds & Kang [18] (state)	2.2-4.5-2.2	--
Olds & Kang [18] (elite)	1.4-4.1-2.0	--
Chan et al. [8]	4.2-4.7-2.9	6.3-4.2-2.0
Song et al. [24]	--	5.0-4.1-2.5
Pieter [19]	1.74-4.68-3.02	2.47-3.08-3.47
Taaffe & Pieter [25]	1.65-4.53-3.59	2.08-3.23-3.98
Karate – Seniors		
Fritzsche & Raschka [12]	2.0-3.7-2.7	3.4-2.4-2.4
Fritzsche [11]	2.3-4.9-2.9	3.6-4.5-2.7
Amusa & Onyewadume [1]	2.5-3.9-3.0	4.4-4.7-1.3
Krawczyk et al. [15]	3.07-5.07-1.79	--
Claessens et al. [9]	2.6-5.2-2.6	--

The same differences are apparent when comparing elite young and elite adult taekwondo-in. For instance, the male junior taekwondo-in are more ectomorphic than their adult colleagues with higher endomorphy [18, 19, 20, 25]. The young female taekwondo-in are similar in ectomorphy but higher in endomorphy than their adult colleagues [19, 20, 25].

Similar physiques are expected of successful young and adult athletes in the same sport [17] as was evident from the global somatotypes. The overlap seems to suggest that at the junior elite level, somatotype plays a role in both males and females, while other factors, such as psychological profile, physiological characteristics and biomechanical efficiency, also have their roles to play in a subjective sport like taekwondo. Physique could then be used as one of the selection criteria to identify and develop talent, keeping in mind tracking issues [16], and the contribution of nutritional considerations and optimal training [7] as well as the within-group variation of any of the dimensions of morphological optimization [17].

Data on body build of recreational young taekwondo-in are scarce. Fadzliana et al. [10] described the physique of recreational Malaysian taekwondo practitioners (18 years) and found no statistical differences between males (3.73-5.45-2.34) and females (4.64-4.86-1.44), although the latter had a higher endomorphic and lower ectomorphic rating. When comparing the junior taekwondo athletes in the current study with their adult counterparts competing at lower levels [8, 18, 24], the difference in the endomorphic component is also evident. This pattern is similar when comparing adult elite and recreational or club taekwondo-in.

It has been suggested that anthropometric determinants in themselves may not be sufficient to predict performance and that experience may play a larger role in the relationship [18]. This was confirmed by Pieter et al. [21], who reported that performance in males was predicted by general taekwondo and competition-specific experience as well as mesomorhy. In the females, performance was related to general taekwondo and competition-specific experience as well as height. Future research should consider physique characteristics in terms of differences in experience, i.e., body build should be investigated taking into account experience.

ACKNOWLEDGMENT

The support of the author's research assistants during data collection is greatly appreciated.

REFERENCES

1. Amusa L., Onyewaddume I. (2001) Anthropometry, body composition and somatotypes of Botswana national Karate players: A descriptive study. Acta Kines. Univ. Tart. 6: 7–14.
2. Bayios I. A., Bergeles N. K., Apostolides N. G., Noutsos K. S., Koskolou, M. D. (2006) Anthropometric, body composition and somatotpye differences of Greek elite female basketball, volleyball and handball players. J. Sports Med. Phys. Fit. 46: 271–280.
3. Bender R., Lange S. (2001) Adjusting for multiple testing – when and how? J. Clin. Epidem. 54: 343–349.

4. Beneke R., Beyer T., Jachner C., Erasmus J., Hütler M. (2004) Energetics of karate kumite. Eur. J. Appl. Physiol. 92: 518–523.
5. Bridge C. A., Jones M. A., Hitchen P., Sanchez X. (2007) Heart rate responses to taekwondo training in experienced practitioners. J. Str. Cond. Res. 21: 718–723.
6. Bouhlel E., Jouini A., Gmada, N., Nefzi, A., Ben Abdallah K., Tabka, Z. (2006) Heart rate and blood lactate responses during taekwondo training and competition. Sci. Sports. 21: 285–290.
7. Carter J. E. L., Honeyman Heath B. (1990) Somaotyping. Development and Applications. Cambridge University Press, Cambridge, UK.
8. Chan K., Pieter W., Moloney K. (2003) Kinanthropometric profile of recreational taekwondo athletes. Biol. Sport. 20: 175–179.
9. Claessens A., Beunen G., Lefevre J., Mertens G., Wellens R. (1986) Body structure, somatotype, and motor fitness of top-class Belgian judoists and karateka. A comparative study. In: Kinanthropometry III, T. Reilly, J. Watkins, J. Borms (eds.). London: E. & F. N. Spon, 53–57.
10. Fadzliana M., Pieter W., Erie Z. Z. (2008) Descriptive anthropometry of recreational adolescent taekwondo practitioners. In: 2008 International Convention on Science, Education and Medicine in Sport. Proceedings Volume I, Guangzhou: People's Sports Publishing House, 28–29.
11. Fritzsche J. (2006) Sportanthropologische Untersuchungen zur Konstitutionstypologie von Kampfkünstlern der Sportart Karate (Elitekarateka). Unpublished Ph.D. thesis, Frankfurt am Main: Johann Wolfgang Goethe Universität.
12. Fritzsche J., Raschka C. (2007) Sportanthropologische Untersuchungen zur Konstitutionstypologie von Elitekarateka. Anthropol. Anz. 65: 1–13.
13. Gualdi-Russo E., Zaccagni L. (2001) Somatotype, role and performance in elite volleyball players. J. Sports Med. Phys. Fit. 41: 256–262.
14. Katić R., Blažević S., Krstulović S., Mulić R. (2005) Morphological structures of elite karateka and their impact on technical and fighting efficiency. Coll. Anthropol. 29: 79–84.
15. Krawczyk B., Sklad M., Jackiewics A. (1997) Heath-Carter somatotypes of athletes representing various sports. Biol Sport. 14: 305–310.
16. Malina R. M., Bouchard C., Bar-Or O. (2004) Growth, Maturation, and Physical Activity. Human Kinetics, Champaign, IL.
17. Norton K., Olds T., Olive S., Graig N. (1996) Anthropometry and sports performance. In: Anthropometrica, K. Norton, T. Olds (eds.). Sydney: UNSW Press, 287–364.

18. Olds T., Kang, S. J. (2000) Anthropometric characteristics of adult male Korean taekwondo players. In: Taekwondo and the New Millennium-Proceedings, Olympic Taekwondo Organizing Committee (ed.). Seoul: Korean National University of Physical Education, 69–75.
19. Pieter W. (1991) Performance characteristics of elite taekwondo athletes. Kor. J. Sport Sci. 3: 94–117.
20. Pieter W. (2001) Somatotypes of young taekwondo athletes: implications for talent identification. In: Proceedings of the 7th International Scientific Conference of the International Association of Sport Kinetics, T. Jürimäe, J. Jürimäe (eds.). Acta Kines. Univ. Tart. 192–195.
21. Pieter W., Mateo C., Bercades L. T. (2002) Determinants of performance in taekwondo. Med. Sci. Sports Exer. 34: S65.
22. Ross W. D., Marfell-Jones M. J. (1991) Kinanthropometry. In: Physiological Testing of the High-Performance Athlete, MacDougall J. D., Wenger H. A., Green H. J. (eds.). Champaign, IL: Human Kinetics Books, 223–308.
23. Rothman K. J. (1990) No adjustments are needed for multiple comparisons. Epidem. 1: 43–46.
24. Song J. K., Sohn D. O., Kim T. W. (1997) Relationship between human physique and physical fitness in collegiate female athletes. In: ICHPER.SD 40th World Congress Proceedings, Seoul, Korea: Kyunghee University, P400 – P402.
25. Taaffe D., Pieter W. (1990) Physical and physiological characteristics of elite taekwondo athletes. In: Commonwealth and International Conference Proceedings. Volume 3. Sport Science. Part 1, Auckland, New Zealand: NZAHPER, 80–88.
26. Wassmer D. J., Mookerjee S. (2002) A descriptive profile of elite U. S. women's collegiate field hockey players. J. Sports Med. Phys. Fit. 42: 165–171.

Correspondence to:
Willy Pieter
Department of Physical Education
University of Asia and the Pacific
Ortigas Center
Pasig City 1605
Philippines

MOOD AND PERFORMANCE IN AIKIDO ATHLETES

W. Pieter[1], **M. S. Pieter**[2]

[1] Department of Physical Education, University of Asia and the Pacific, Pasig City, Philippines

[2] Department of Neurosciences, School of Medical Sciences, Science University of Malaysia, Kelantan, Malaysia

ABSTRACT

The purpose of this study was to assess the mood profile of successful and less successful aikidoka (aikido athletes). Subjects (45 men, 30.51 $\pm$ 8.06 years, and 17 women, 27.29 $\pm$ 6.94 years) were administered the Brunel Mood Scale at a regional open aikido tournament in the south of England about one hour prior to competition. A 2-way (Gender x Performance) ANOVA was employed to determine the differences in mood between male and female winning and losing aikidoka. The women scored higher on tension (5.58 $\pm$ 2.74 vs. 4.04 $\pm$ 3.02) ($p = 0.049$, $eta^2 = 0.065$). The data were collapsed over performance and mood was compared between gender. The men (0.76 $\pm$ 1.81 vs. 0.06 $\pm$ 0.24) were more depressed ($p = 0.015$; $d = 0.68$) and fatigued (3.16 $\pm$ 4.17 vs. 1.53 $\pm$ 1.18, $p = 0.021$; $d = 0.61$). The depressed mood males scored higher on anger (2.27 $\pm$ 4.84 vs. 0.24 $\pm$ 0.82, $p = 0.021$, $d = 0.72$) and were more fatigued (5.45 $\pm$ 4.37 vs. 2.41 $\pm$ 3.89, $p = 0.034$, $d = 0.74$). It is concluded that the model by Lane and Terry [5] was supported by the current investigation.

Key words: mood, performance, aikido

INTRODUCTION

It has been suggested that a positive mental health state is related to success in sport, i.e., "success in sport is inversely related with psychopathology" [11]. Mental health state refers to the athletes' response to training rather than their baseline psychological profile. Compared to less successful athletes and the general population, successful athletes show lower levels of anxiety, neuroticism, tension, depression, fatigue and other negative moods but they score higher on vigor, leading to the so-called iceberg profile [11, 12].

Morgan's mental health model relates success in any given sport to a positive psychological profile as measured by mood states. A greater incidence of a decrease in performance is implicated in a less desirable mood profile. Several studies have shown this relationship to hold at both the elite and non-elite levels [e.g., 3, 4, 13, 14]. However, more recent research has shown that the iceberg profile may only distinguish between athletes and non-athletes, rather than between different skill levels [17].

McGowan and Miller [7] compared karate semifinalists in fighting and forms with those placed lower using the Profile of Mood States (POMS) [10] and found no difference in any of the mood subscales. When year-long competitions were taken into account, however, the successful competitors scored higher on anger. The authors hypothesized that the successful athletes use angry imagery to "psych' themselves up for competition. The same pattern was found in experienced karate athletes with first degree black belts scoring higher on anger than their higher ranked colleagues [9]. The investigators hypothesized that higher ranked black belts may be more self-confident, so they may not need to use anger as a coping mechanism.

In a related study, McGowan and associates [8] compared karate athletes from different skill levels as indicated by belt rank and found that black belts were more fatigued than white belts at a state championship. At regional tournaments, a similar picture emerged with the black belts scoring higher on fatigue than brown, colored and white belts. The authors concluded that the iceberg profile may not be exhibited by even successful athletes one day prior to competition.

Terry and Slade [21] also reported that karateka (karate athletes) who won showed more anger as well as vigor, but they scored lower on the other moods. The iceberg profile was demonstrated for the successful karateka, although anger was above that predicted by the mental health model [11]. The authors reported that mood profile was an exceptionally good predictor of karate performance with losers scoring high on several subscales.

Lane and Terry [5] developed a conceptual model in which it was suggested that 1) relationships among independent moods will be stronger in those high in depression; 2) high depression will be associated with high scores in anger, confusion, fatigue and tension with low vigor; 3) regardless of the level of depression, vigor will be positively and linearly related to performance, while fatigue and confusion will be negatively related to performance; 4) in those with high depression, tension and anger will be inversely related to performance, but will show a curvilinear relationship in those low in depression.

Lane et al. [6] showed that tension and anger in kickboxers were associated with losing when accompanied by depression. Depression was associated with high scores on tension, anger, fatigue and confusion. Wong et al. [22] reported that only successful female adolescent karateka scored higher on anger, while several negative moods were higher in both male and female depressed mood groups.

No mood studies to date have been conducted on aikidoka (aikido athletes). The purpose of this investigation, therefore, was to appraise the mood profile of successful and less successful aikidoka. To this end, the relationship between mood profile and performance was assessed. In addition, the association between tension, anger, vigor, fatigue and confusion in aikidoka with depressed and non-depressed mood was estimated.

METHODS

The Brunel Mood Scale (BRUMS) [20] was administered to all black belt participants (45 men, 30.51 $\pm$ 8.06 years, and 17 women, 27.29 $\pm$ 6.94 years) at a regional open aikido tournament in the south of England about one hour prior to competition. The response set used was 'How are you feeling right now?'

A 2-way (Gender x Performance) ANOVA was employed to determine the differences in mood between male and female winning and losing aikidoka. The level of significance was set at 0.05. It was decided not to adjust the type 1 error for multiple comparisons, because the interest was in the comparisonwise error rate as the data were generated through actual observations. As well, the objective was to unearth any possible leads regarding the relationship between the independent and dependent variables [1, 18].

RESULTS

Table 1 shows descriptive statistics for mood states in aikidoka by gender and performance. There was no 2-way interaction for any of the mood subscales and neither was there a main effect for Performance ($p > 0.05$ each). The women, however, scored higher on tension (5.58 ± 2.74 vs. 4.04 ± 3.02) ($p = 0.049$) but the effect was trivial ($eta^2 = 0.065$).

Table 1 Means and standard deviations in mood states in black belt aikidoka by gender and performance

	Men		Women	
	Winners	Losers	Winners	Losers
n	16	29	6	11
Tension	4.19 ± 3.23	3.97 ± 2.95	5.83 ± 3.13	5.91 ± 2.66
Depression	0.44 ± 0.96	0.93 ± 2.14	0.00 ± 0.00	0.00 ± 0.00
Anger	0.06 ± 0.25	1.10 ± 3.16	0.17 ± 0.41	0.36 ± 0.67
Vigor	6.56 ± 3.31	8.07 ± 3.31	6.67 ± 1.21	7.00 ± 2.53
Fatigue	2.38 ± 3.05	3.59 ± 4.67	2.17 ± 0.75	1.82 ± 1.25
Confusion	1.25 ± 1.73	1.97 ± 3.18	1.50 ± 1.05	1.55 ± 1.51

Since no differences were found between successful and less successful competitors by sex, the data were collapsed over performance and mood states were compared between gender using an independent t-test.

Table 2 displays the means and standard deviations for mood states by gender. The women scored higher on tension ($p = 0.032$, $d = 0.64$), while the men were more depressed ($p = 0.015$, $d = 0.68$) and fatigued ($p = 0.021$, $d = 0.61$).

Table 2 Descriptive statistics for mood states in black belt aikidoka by gender

	Men	Women
Tension	4.04 ± 3.02	5.88 ± 2.74
Depression	0.76 ± 1.81	0.06 ± 0.24
Anger	0.73 ± 2.57	0.29 ± 0.59
Vigor	7.53 ± 3.35	6.88 ± 2.12
Fatigue	3.16 ± 4.17	1.53 ± 1.18
Confusion	1.71 ± 2.75	1.53 ± 1.33

Following the suggestion by Lane et al. [6] and Lane and Terry [5], the subjects were divided into those who showed depressed mood and those who did not. Since only one female aikidoka qualified for the "depressed mood" category, the analysis was restricted to the males (see Table 3). An independent t-test was used for the analysis, while Pearson correlations between subscales were also calculated.

Table 3 Descriptive statistics for mood states in male black belt aikidoka as a function of depressed mood

	Non-depressed (n = 34)	Depressed (n = 11)
Tension	3.76 ± 3.02	4.91 ± 2.99
Depression	0.00 ± 0.00	3.09 ± 2.55
Anger	0.24 ± 0.82	2.27 ± 4.84
Vigor	7.91 ± 3.40	6.36 ± 3.04
Fatigue	2.41 ± 3.89	5.45 ± 4.37
Confusion	1.47 ± 2.35	2.45 ± 3.78

The depressed mood aikidoka scored higher on anger ($p = 0.021$, $d = 0.72$) and they were also more fatigued ($p = 0.034$, $d = 0.74$). Table 4 displays the correlation matrix between mood subscales in the non-depressed mood males. There were associations between tension and confusion ($p = 0.001$), between anger and fatigue ($p = 0.043$), anger and confusion ($p = 0.004$) as well as between fatigue and confusion ($p < 0.001$).

Table 4 Correlations between pre-competition mood subscales in non-depressed male aikidoka

	Tension	Depression	Anger	Vigor	Fatigue	Confusion
Tension	–					
Depression		–				
Anger	0.02	–	–			
Vigor	–0.14	–	0.07	–		
Fatigue	0.07	–	0.35*	–0.05	–	
Confusion	0.55*	–	0.48*	–0.09	0.66*	–

Table 5 depicts the correlation matrix between mood subscales in the depressed mood males. There were associations between depression and anger ($p < 0.001$), depression and confusion ($p < 0.001$), as well as between anger and confusion ($p < 0.001$).

Table 5 Correlations between pre-competition mood subscales in depressed aikidoka

	Tension	Depression	Anger	Vigor	Fatigue	Confusion
Tension	–					
Depression	0.21	–				
Anger	0.21	0.96*	–			
Vigor	0.35	0.03	0.12	–		
Fatigue	–0.01	0.27	0.26	–0.16	–	
Confusion	0.20	0.88*	0.91*	0.29	0.40	–

DISCUSSION

McGowan and Miller [7] initially also did not find any difference in psychological mood between successful and less successful karateka. However, when a longer competition period was taken into account, the winners were shown to score higher on anger, which was confirmed by later research [9, 19, 21). Anger was also found to be higher in young successful taekwondo athletes, as well as tension [15], while Wong et al. [22] reported higher anger in female successful karateka.

One explanation may be that aikidoka spend time cultivating the self, which is not necessarily part of the curriculum for their counterparts in karate and taekwondo. In other words, the meditative aspects of aikido may have played a role in the athletes not using anger to psych themselves up. Another explanation may be that experience, both general aikido experience and aikido-specific competition experience, may have masked the relationship between mood and performance as was suggested for taekwondo [15]. Future research on aikidoka should include experience in the model to elucidate the effects, if any, of mood on performance.

Tension, depression and fatigue differentiated the women from the men with the former scoring higher on tension but lower on depression and fatigue. It is not clear why the women were more tense. It could be that they viewed their opponents as more difficult to beat, as was found in female softball players [2], which subsequently led to higher tension. Including experience in the model, as alluded to above, may shed light on the association between gender, tension and performance.

When depression was used to categorize the male aikidoka, the depressed mood athletes scored higher on anger and fatigue, as predicted by the conceptual model advanced by Lane and Terry [5]. The effect sizes were also large.

The correlations between subscales seem to confirm Lane's and Terry's [5] conceptual model. A significant positive association between fatigue and confusion is suggested to have a debilitative effect on performance in non-depressed mood individuals. On the other hand, the positive correlations between anger and depression as well as anger and confusion in depressed mood athletes are predicted to have debilitative effects on performance. In other words, although the aikido athletes may not have used anger to psych themselves up, it may still have played a role by virtue of its relationship with other negative moods.

Figure 1 displays the mood profile of aikidoka by gender compared to norms of adult athletes [20]. Neither the men nor the women showed the iceberg profile predicted by Morgan [11] as was also found in young taekwondo athletes using norms for athletes [15]. Other investigators, using McNair et al.'s [10] norms, also failed to find the iceberg profile [e.g., 2, 16]. Morgan [1] developed his model based on McNair et al.'s [10] norms. Future research may want to elucidate the relation between mood, performance and the mental health model by using norms for athletes.

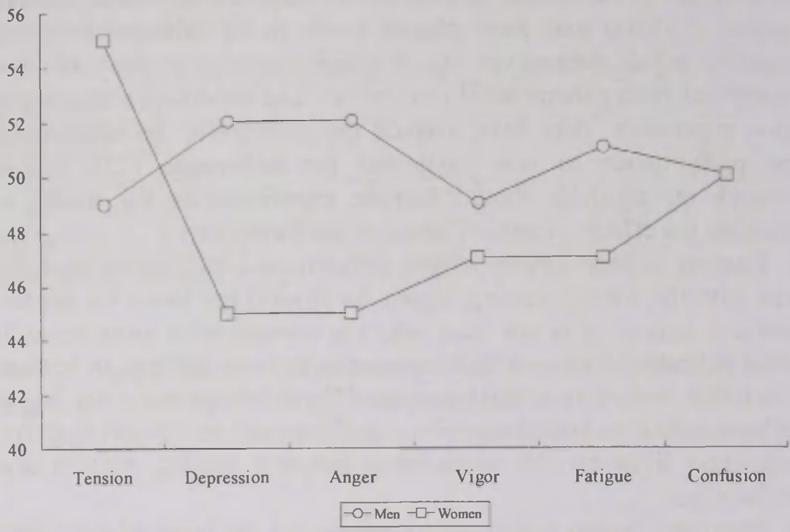


Figure 1. Mood profiles of black belt male and female aikidoka

ACKNOWLEDGMENT

The authors are grateful to Shaz John for assistance in data collection.

REFERENCES

1. Bender R., Lange S. (2001) Adjusting for multiple testing – when and how? J. Clin. Epidem. 54: 343–349.
2. Coker C., Mickle A. (2000) Stability of the iceberg profile as a function of perceived difficulty in defeating an opponent. Percept. Mot. Skills. 90 (3, Part 2): 1135–1138.
3. Frazier S. E. (1989) A comparison of team mood state profiles utilizing the mental health model. J. Hum. Mov. Stud. 16: 91–99.
4. Frazier S. E. (1988) Mood state profiles of chronic exercisers with different abilities. Int. J. Sport Psych. 19: 65–71.

5. Lane A. M., Terry P.C. (2000) The nature of mood: development of a conceptual model with a focus on depression. J. Appl. Sport Psych. 12: 16–33.
6. Lane A. M., Terry P. C., Karageorghis C. I., Lawson J. (1999) Mood states as predictors of kickboxing performance: a test of a conceptual model. J. Sports Sci. 17: 57–58.
7. McGowan R. W., Miller M. J. (1989) Differences in mood states between successful and less successful karate participants. Percept. Mot. Skills. 68: 505–506.
8. McGowan R. W., Miller M. J., Henschen K. (1990) Differences in mood states between belt ranks in karate tournament competitors. Percept. Mot. Skills. 71: 147–150.
9. McGowan R. W., Pierce E. F., Jordan D. (1992) Differences in precompetitive mood states between black belt ranks. Percept. Mot. Skills. 75: 123–128.
10. McNair D. M., Lorr M., Dropleman L. F. (1971) Profile of Mood States Manual. Educational and Industrial Testing Service, San Diego.
11. Morgan W. P. (1985) Selected psychological factors limiting performance: a mental health model. In: Limits of Human Performance. The Academy Papers #18, D. H. Clarke H. M. Eckert (eds.), Champaign, IL: Human Kinetics Publishers, 70–80.
12. Morgan W. P. (1980) Test of champions: the iceberg profile Psych Today. 13: 92–93, 97–99, 102, 108.
13. Morgan W. P., Brown D. R., Raglin J. S., O'Connor P. J., Ellickson K. A. (1987) Psychological monitoring of overtraining and staleness. Brit. J. Sports Med. 21: 107–114.
14. Morgan W. P., Costill D. L., Flynn M., Raglin J. S., O'Connor P. J. (1988) Mood disturbance following increased training in swimmers. Med. Sci. Sports Exerc. 20: 408–414.
15. Pieter W., Wong R. S. K., Ampongan C. (2006). Mood and experience as correlates of performance in young Filipino athletes. Acta Kines. Univ. Tart. 11: 64–72.
16. Prapavessis H., Berger B., Grove J. (1992) The relationship of training and pre-competition mood states to swimming performance: an exploratory investigation. Aust. J. Sci. Med. Sport 24: 12–17.
17. Renger R. (1993) A review of the Profile of Mood States (POMS) in the prediction of Athletic success. J. Appl. Sport Psych. 5: 78–84.
18. Rothman K. J. (1990) No adjustments are needed for multiple comparisons. Epidem. 1: 43–46.

19. Ruiz M., Hanin Y. (2003) Anger states in top karate athletes: an idiosyncratic description, II International Congress of Psychology Applied to Sport, Madrid, Spain.
20. Terry P. C., Lane A. M. (2003) User Guide for the Brunel Mood Scale (BRUMS). University of Southern Queensland, Australia, Toowoomba and University of Wolverhampton, Wolverhampton, UK.
21. Terry P. C., Slade A. (1995) Discriminant effectiveness of psychological state measures in predicting performance outcome in karate competition. Percept. Mot. Skills, 1: 275–286
22. Wong R. S. K., Thung J. S., Pieter W. (2006) Mood and performance in young Malaysian karateka. J. Sport Sci. Med. 5, Combat Sports Special Issue: 54–59.

Address for correspondence:
Willy Pieter
Department of Physical Education
University of Asia and the Pacific
Ortigas Center, Pasig City 1605
Philippines

PHYSIOACOUSTIC THERAPY: PLACEBO EFFECT ON RECOVERY FROM EXERCISE-INDUCED MUSCLE DAMAGE

P. M. Tiidus[1], R. Markoulakis[1], D. Murray[1], P. J. Bryden[1], H. Ahonen-Eerikäinen[2]

[1] Department of Kinesiology & Physical Education
[2] Department of Music Therapy, Wilfrid Laurier University, Waterloo ON, Canada

ABSTRACT

We evaluated claims that physioacoustic therapy can enhance muscle healing following damaging exercise. Untrained subjects were randomly assigned to control (C), placebo (P) or treatment (T) groups. All groups performed 70 eccentric triceps contractions followed by; no treatment (C), sham physioacoustic treatment (P), or actual physioacoustic therapy (T) on days 1–4 post-exercise. Muscle soreness and isometric and concentric triceps peak torque were determined pre-exercise and on days 1–4 and 7 post-exercise. The T group received physioacoustic therapy for 30 min/day on the treatment days. The P group believed they received physioacoustic therapy, although the chairs were turned off. Peak torques were depressed ($P < 0.05$) on days 1–3 in all groups and returned to pre-exercise values by days 4–7 in both P and T groups. C group peak torques remained depressed ($P < 0.05$) through day 7. Soreness was elevated ($P < 0.05$) in all groups on days 1–2 post-exercise. P and T groups reported no soreness by day 3 while the C group remained sore ($P < 0.05$) through days 3–4. The T group recovered soreness and force faster than C but at a similar rate to the P group. The effectiveness of physioacoustic therapy in enhancing post-exercise muscle healing may be attributable to a placebo effect.

Key words: muscle soreness, physioacoustic therapy, placebo effect, muscle damage

INTRODUCTION

Various forms of sound induced vibration have been developed over the past several decades primarily as potential therapeutic or relaxation inducing modalities [12, 18]. Mostly through the work of Scandinavian therapists music or low frequency sound induced vibration has been used as a relaxation or a “therapeutic” modality with physically or mentally handicapped children, deaf individuals or those with brain injuries, chronic pain, anxiety or other disorders [10, 24].

A specific “physioacoustic” method and chair were developed in Finland in the late 1980’s to treat handicapped and brain injured individuals, however anecdotal information soon emerged suggesting other possible uses in treating muscle tension, pain sensation, high blood pressure and other clinical conditions [9, 12].

The reclining physioacoustic chair (Next Wave UK Ltd, Finland) is fitted with six audible speakers and a transformer, that controlled by a computer, generate low frequency (27–113 Hz) sinusoidal sound waves. These waves can be pulsed and/or varied by direction (from top to bottom of the body or vise-versa) or scanned to try to match theoretical “resonance frequencies” of muscles [12]. Butler [3] has suggested that physioacoustic induced vibration differs from mechanical vibration in that: 1. mechanical vibration causes numbness while physioacoustic vibration does not, 2. mechanical vibration causes muscle contraction while physioacoustic vibration induces muscle relaxation, 3. mechanical vibration induces muscle fatigue and has only passing effects on dampening muscle pain while physioacoustic vibration does not induce muscle fatigue and has longer lasting analgesic effects.

Physioacoustic treatment is currently practiced in numerous countries primarily in northern Europe and in parts of North America for multiple therapeutic purposes including sports medicine and promotion of muscle healing [9]. According to case studies and practitioner experiences, physioacoustic treatment may help relieve pain and reduce the length of the rehabilitation period when treating sports injuries, including acute muscular trauma and overuse injury [18, 19]. The physioacoustic method has been approved by the United

States Food and Drug Administration as a class II (low risk, non-invasive) device and allowed three claims: improvement of circulation, release of muscle tension and alleviation of minor pain [12]. There is anecdotal information that the physioacoustic device has also been used by a number of European football and hockey teams as well as by other athletes such as skiers and ski jumpers as a means of recovery/ regeneration following intense physical activity. Its use, while still regional, is growing in popularity.

Despite the claims of efficacy and its use by athletic populations as a means to enhance muscle recovery, there is almost no experimental data currently available to verify the alleged benefits of physioacoustic therapy. In addition, there is currently no plausible physiological theory as to how physioacoustic therapy may be able to accelerate muscle healing, repair or recovery. Burke and Thomas [2] found some evidence of pain reduction due to physioacoustic therapy in conjunction with physiotherapy in patients with total knee replacement. Burke [1] also reported positive effects of physioacoustic therapy on pain management in post-operative gynecological patients. Pain reduction, relaxation and improved mood have also been reported with the use of physioacoustic therapy and sound/music therapy in various other clinical and post-operative patients [3, 12, 17]. However no studies have looked directly at any possible benefits of physioacoustic therapy on recovery of muscle following damaging exercise or overtraining.

This is the first study which has attempted to determine if physioacoustic therapy would have any effect on muscle recovery or soreness sensation following eccentric exercise induced muscle damage. The eccentric exercise-induced muscle damage and recovery model and its time-course has been well described in the literature and is similar to the muscle disruption seen in over-trained athletes or individuals who have performed unaccustomed exercise [4, 5, 6]. The eccentric exercise-induced muscle damage model has also been previously used to assess the effectiveness of other therapeutic modalities such as massage and ultrasound on muscle recovery [15, 21]. It was hypothesized that physioacoustic therapy would significantly enhance the rate of recovery of indices of muscle damage and soreness sensation following eccentric muscle exercise relative to control and placebo treatment groups.

METHODS

The study was approved by the Wilfrid Laurier University Human Research Ethics Board. All subjects signed informed consent prior to participation in the study.

Subjects: Thirty one (7 male and 24 female) university students, age 20.7±3.1 y, weight 69.1±10.7 kg completed the study. All subjects were healthy, with no physical impairments. None of the subjects had participated in any systematic upper body training in the past 4 months or had any upper limb injuries.

Procedures: Subjects were randomly divided into 3 groups: a physioacoustic treatment group (T) n = 12, a placebo treatment group (P) n = 12 and a control-no treatment group (C) n = 7. Because of problems in experimental logistics, data from several of the C group subjects was not complete, hence the uneven number of subjects in the groups.

All subjects received two brief familiarization sessions on the CYBEX NORM apparatus prior to the data collection in order to become accustomed to generating maximum isokinetic and isometric triceps muscle contractions. The T and P groups were also exposed for brief periods to the physioacoustic chair on two occasions prior to the start of the experiment. In the case of the T group, the physioacoustic chairs produced a range of acoustic vibrations to acclimate them to the vibrations. The placebo group was also exposed to the physioacoustic chairs for the same time periods with the chair turned off.

In order to induce muscle damage and soreness similar to that seen with athletic overtraining or following unaccustomed exercise, all subjects performed 7 sets of 10 maximum effort eccentric isokinetic (60°/sec) triceps contractions using the CYBEX NORM [6]. Subjects were given 1 minute rest between sets and warmed up with 10 submaximum contractions prior to initiating the maximum effort sets. All subjects were verbally encouraged to maintain maximum efforts.

On days 1, 2, 3, 4 following the eccentric triceps contraction protocol, the T group received 30 min physioacoustic treatments designed by Marco Kärkkäinen, an experienced physioacoustic therapist from Finland, specifically to treat exercise-induced muscle damage. An outline of physioacoustic treatment protocol is depicted in Table 1. The P group was also exposed to the physioacoustic chairs for 30 min on the same days as the T group. However, the chairs were turned off and the subjects were lead to believe that the treatment was occurring. The C group were not exposed to physioacoustic chairs.

Table 1. Physioacoustic therapy, treatment protocol

Day	Treatment type	Main Frequency (Hz)	Duration (min)
1	Acoustic Massage	40	30
2	Acoustic Relaxation	50	30
3	Acoustic Relaxation	50	30
4	Acoustic Relaxation	60	30

Outcome measures: Prior to and on days 1, 2, 3, 4 & 7 following the eccentric triceps contraction protocol, all subjects were also evaluated for isometric and eccentric isokinetic (60°/sec) triceps peak torques and for muscle soreness sensation. Subjects were asked to perform isometric and eccentric triceps contractions using the CYBEX NORM. Three trials with 30–60 sec rest between trials for each of the isometric and eccentric contractions were performed with the best of the three trials recorded. Each subject's baseline peak torque (as determined prior to the eccentric exercise protocol) was set as 100% with subsequent force loss and recovery calculated as a percentage of the baseline. Muscle force (peak torque) measures are reliable non-invasive gross indicators of muscle damage and repair as muscle force is typically lost following damaging exercise and slowly recovers over several days as muscle recovers [5, 23].

Muscle soreness was evaluated by asking subjects to rate their triceps muscle soreness while performing light contractions on a scale of 1–10 with 1 representing "not sore at all" and 10 representing "ext-remely sore" [14, 20]. Muscle soreness is also a quantifiable indicator of physiological responses to muscle damage and its time-course has been well described in the literature [6]. All measures were made immediately prior to the daily physioacoustic treatment or placebo treatments (T and P groups) and at the same time as the measures for the C group.

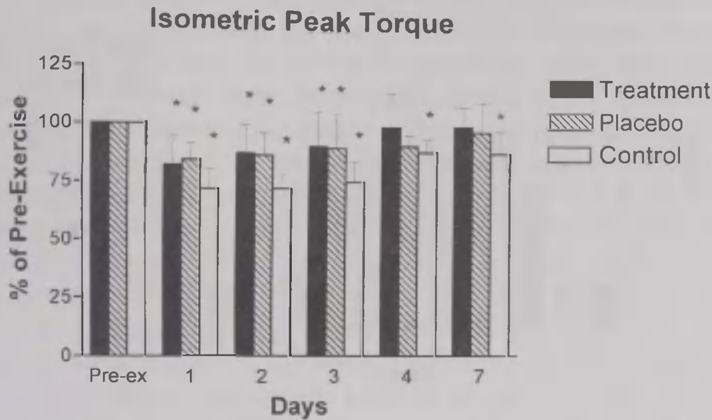
Statistical Analysis: Data was analyzed using SPSS statistical package. Analysis of Variance (ANOVA) as pairwise comparisons at each time point (within groups) was performed. Significance was set at $P < 0.05$.

RESULTS

The results for post-eccentric exercise triceps isometric and eccentric isokinetic peak torque measures are depicted in Figure 1a and 1b respectively. For normalization, the data are expressed as a percentage of pre-exercise peak torques, however measures were made and statistics performed on the data as expressed in Newton metres (Nm) per kg body weight. Isometric and eccentric triceps muscle peak torque was significantly ($P < 0.05$) reduced relative to the pre-eccentric exercise protocol in all groups on days 1 and 2 post-exercise. By day 3 or 4 and afterward both the T and P group triceps isometric (day 4) and eccentric (day 3) peak torques were no longer significantly different ($P > 0.05$) from pre-exercise values suggesting that triceps muscle force had essentially recovered by day around day 3–4 in these groups. Interestingly both the isometric and eccentric peak torques for the C group were still significantly depressed relative to pre-exercise baseline at day 7 post-exercise, suggesting that full muscle force recovery for the C group had not yet occurred.

The results for muscle soreness sensation are depicted in Figure 2. All groups experienced significantly ($P < 0.05$) elevated muscle soreness on days 1 and 2 post exercise. While the T and P groups soreness levels were no longer significantly different ($P > 0.05$) from pre-exercise values by day 3 and subsequent days, the C groups continued to experience significantly elevated ($P < 0.05$) soreness levels on days 3 and 4 post-exercise and did not return to pre-exercise levels ($P > 0.05$) until day 7 post-exercise.

A



B

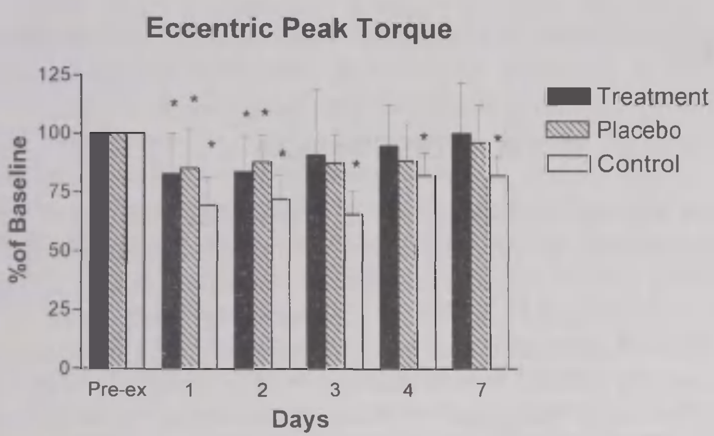


Figure 1. Triceps muscle isometric (a) and eccentric isokinetic-60□/sec (b) peak torques prior to and up to 7 days post-eccentric exercise as a percent of pre-exercise peak torque for physioacoustic treatment, placebo treatment and control (no treatment) groups. Data expressed at mean ± SD.

*Significant difference between group at this time point and its pre-exercise value ($P < 0.05$).

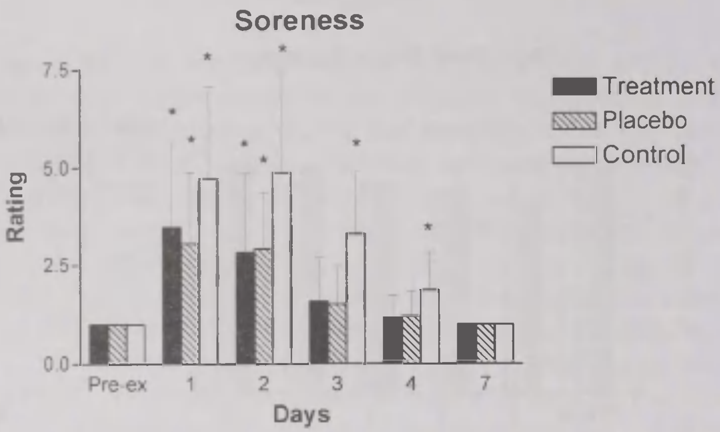


Figure 2. Triceps muscle soreness prior to and up to 7 days post-eccentric exercise for physioacoustic treatment, placebo treatment and control (no treatment) groups. Data expressed at mean ± SD.

*Significant difference between group at this time point and its pre-exercise value ($P < 0.05$).

DISCUSSION

This is the first controlled study to examine the potential of physio-acoustic therapy to influence indices of muscle damage and recovery following eccentric muscle contractions. As expected, all experimental groups experienced significant decreases in both isometric and eccentric triceps peak torque and increased muscle soreness following eccentrically induced muscle damage. Muscle strength loss and regain is a commonly recognized as being quantitatively reflective of the degree of muscle damage and recovery [23] and has been previously used in evaluation of the effectiveness of other therapeutic modalities affecting muscle repair [15, 21]. Changes in muscle force consequent to damage are reflective both of muscle structural damage and muscle excitation-contraction uncoupling [16, 22]. Muscle soreness is also commonly assessed as an indirect indicator of muscle disruption [23] and while not necessarily directly related to rate of muscle force recovery [23] may reflect muscle inflammatory processes associated with muscle damage [13].

Contrary to our hypothesis, both the physioacoustic treatment (T) and the placebo treatment (P) returned to pre-exercise muscle force and muscle soreness levels significantly sooner following eccentric muscle contractions than the untreated control (C) group and at times that were not different from each other. These results suggest that physioacoustic treatment appeared to enhance the rate of recovery of indices of muscle damage relative to no treatment. However, since the placebo treatment group also experienced a similarly enhanced rate of recovery, the effects of the physioacoustic treatment cannot be attributed to any physiological effects on muscle repair mechanisms or soreness sensation and must instead be attributed to placebo effect alone. Physioacoustic therapy is not unique in this respect as other studies have also found that the placebo effect may contribute to some or all of the alleged therapeutic benefits of various other complementary medicine therapies [11].

The placebo effect has been extensively documented as having significant analgesic influence and on markedly enhancing recovery from various forms of injury and disease [7]. Hence placebo groups are commonly included and indeed required in studies examining the potential of various therapeutic interventions. However, to demonstrate the specific physiological effectiveness of any drug, mainstream medical treatment or complementary medical therapy, the effects of the treatment must be clearly demonstrated to exceed that of any potential placebo effect alone [8]. In this regard, this study was unable to demonstrate any specific benefit of physioacoustic therapy beyond that which could be explained by placebo effect. Hence, based on these results, physioacoustic therapy cannot yet be recommended as a modality to enhance muscle physical or performance recovery in athletes or in individuals who have experienced over-use injury.

As this was the first study to examine the potential of physioacoustic therapy in affecting recovery from muscle damage, more extensive research using different models, clinical conditions and physioacoustic treatment paradigms still needs to be performed to fully explore the potential for physioacoustic therapy in treating muscle damage and in influencing recovery from over-training or over-work related muscle performance decrements.

In conclusion, physioacoustic therapy failed to enhance indices of muscle recovery following eccentric contraction induced damage beyond that seen with placebo treatment. More extensive research with a wider variety of treatment and injury paradigms is needed to fully document the potential (or lack there of), of physioacoustic treatment in athletic or other therapeutic settings.

REFERENCES

1. Burke M. A. (1997) Effects of physioacoustic intervention on pain management of postoperatiave gynecological patients. In: Music vibration and health, Wigram T., Dileo C. (eds.) Cherry Hill N. J.: Jeffrey Books, 107–112.
2. Burke M. A., Thomas K. (1997) Use of physioacoustic therapy to reduce pain during physical therapy for total knee replacement patients over age 55. In: Music vibration and health, Wigram T., Dileo C. (eds.) Cherry Hill N. J.: Jeffrey Books, 99–106.
3. Butler C. (1999) Physioacoustic therapy with post-surgical and critically ill patients. In: Music therapy and medicine: theoretical and clinical applications, American Music Therapy Association, Silver Springs MD, American Music Therapy Association, 31–39.
4. Clarkson P. M., Nosaska K., Braun B. (1991) Muscle function after exercise-induced muscle damage and rapid adaptation. Med. Sci. Sports Exerc. 24: 512–520.
5. Clarkson P. M., Sayers S. P. (1999) Etiology of exercise-induced muscle damage. Can. J. Appl. Physiol. 24: 234–248.
6. Cleak M. J., Eston R. G. (1992) Muscle soreness, swelling stiffness and strength loss after intense eccentric exercise. Br. J. Sports Med. 26: 267–272.
7. Harrington A. (eds.) (1999) The placebo effect: an interdisciplinary exploration. Cambridge MA: Harvard University Press.
8. Kaptchuck T. J., Edwards R. A., Eisenberg D. M. (1996) Complementary medicine: efficacy beyond the placebo effect. In Complementary medicine, an objective appraisal. Ernst E., (eds.) Oxford UK, Butterworth Heinemann, 42–70.
9. Karkkäinen M. (2006) Reflections on physioacoustics-the new era of sound vibration treatment. Sound Effects. 3: 6–9.
10. Karkkäinen M., Mutsui J. (2006) The effects of sound based vibration treatment on the human mind and body: The physioacoustic method. Sound Effects 3: 9–12.
11. Kleijnen J., de Craen A. J. M. (1996) The importance of the placebo effect: a proposal for further research. In Complementary medicine, an objective appraisal. Ernst E., (eds.) Oxford UK, Butterworth Heinemann, 31–41

12. Lehikoinen P. (1997) The Physioacoustic method. In: Wigram Music vibration and health. T, Dileo C. (eds.) Cherry Hill N. J.: Jeffrey Books, 42–47.
13. MacIntyre D. L, Reid W. D., McKenzie D. C. (1995) Delayed onset muscle soreness: the inflammatory response to muscle injury and its clinical implications. Sports Med. 20: 24–40.
14. Mattacola C. G., Perrin D. A., Gansnedeer B. M. et al. (1997) A comparison of visual analog and graphic rating scales for assessment of pain following delayed onset muscle soreness. J. Sport Rehabil. 6: 38–46.
15. Plaskett C., Tiidus P. M., Livingston L. (1999) Ultrasound treatment does not affect post-exercise muscle strength or soreness sensation. J. Sport Rehabil. 8: 1–9.
16. Proske U., Allen T. J. (2005) Damage to skeletal muscle from eccentric exercise. Exerc. Sport Sci. Rev. 33: 98–104.
17. Salamon E., Kim M., Beaulieu J. et al. (2003) Sound therapy induced relaxation: down regulating stress processing and pathologies. Med. Sci. Monit. 9: 116–121.
18. Skille P., Wigram T. (1995) The effects of music, vocalization and vibrations on brain and muscle tissue: In: Studies in vibroacoustic therapy. The art and science of music therapy: a handbook. Wigram T., Saperston B., West R. (eds.) London: Harwood Academic, 23–57.
19. Skille O., Wigram T., Weeks L. (1989) Vibroacoustic therapy: The therapeutic effect of low frequency sound on specific physical disorders and disabilities. J. Br. Music Ther. 3: 6–10.
20. Tiidus P. M., Ianuzzo C. D. (1983) Effects of intensity and duration of muscular exercise on delayed soreness and serum enzyme activities. Med. Sci. Sports Exerc. 15: 461–465.
21. Tiidus P. M., Shoemaker J. K. (1995) Effleurage massage, muscle blood flow and long-term post-exercise strength recovery. Int. J. Sports Med. 16: 478–483.
22. Warren G. L., Ingalls C. P., Lowe D. A. et al. (2001) Excitation-contraction uncoupling: Major role in contraction-induced muscle injury. Exerc. Sport Sci. Rev. 29: 82–87.
23. Warren G. L., Lowe D. A., Armstrong R. B. (1999) Measurement tools used in the study of eccentric contraction-induced injury. Sports Med. 27: 43–59.
24. Wigram T., Dileo C. (eds.) (1997) Music vibration and health. Cherry Hill N. J.: Jeffrey Books.

ACKNOWLEDGMENTS

We acknowledge the assistance of Marco Kärkkäinen in developing the physioacoustic therapy protocol and Angela Walzak for technical assistance in developing the eccentric exercise protocol.

Correspondence to:
Peter M. Tiidus
Department of Kinesiology & Physical Education
Wilfrid Laurier University
Waterloo ON
Canada

INSTRUCTION TO AUTHORS

Acta Kinesiologiae Universitatis Tartuensis is a multidisciplinary (publishing papers on diverse subjects from sports and exercise sciences) annual publication.

Manuscripts are accepted for consideration with the understanding that their contents not been published elsewhere. Manuscripts are read through by the editor and by two reviewers in blind review process, which takes 8–10 weeks.

Manuscripts are to be submitted in English. Submit three clear copies of the manuscripts to the editor. Maximum volume of text is 10 pages, maximum total volume is 15 pages. Type the manuscripts double-spaced on one side of A4 paper with margin of 3 cm on the left side.

The manuscripts should be arranged an following

1. Title page

Title of the article in capital letters, names of authors, authors institution, name and address of the principal author, up to 5 key words. For blind review, a second title page is needed that contains only the title.

2. Abstract (up to 200 words, separate sheets).
3. Text

The text should contain the following sections: Introduction, Materials and Methods, Results, Discussion, References, Acknowledgements if any. Tables and Figures should be presented on separate sheets. Figures should be professional in appearance and have clean, crisp lines. Identify each Figure by marking lightly on the back, indicating. Figure number, top side and abbreviated title of manuscripts. Legends for the Figures should be submitted on a separate sheet. Tables should be double-spaced ion separate sheet and include a brief title. The SI units should be used in presenting results.

Each citation in the text must be noted by number in parenthesis and must appear in the reference list as well. Each entry in the reference list must be double-spaced, arranged alphabetically and numbered serially by author with only reference per number. Non-english papers should be cited in the original language.

Entries in the reference list should be as follows:

1. Sarna S., Kaprio J. (1994) Life expectancy of former elite athletes. Sports Med. 17 (3): 149–151
2. Gurpide E. (1975) Tracer methods in hormone research. Springer Verlag, New York
3. Morgan W. P., Borg G. (1976) Perception of effort in the prescription of physical activity. In: humanistic and mental health aspects of sports, exercises, and recreation, T. Craig (ed). Chicago: Am. Med. Assoc. 256–259
4. Paoletti R. (1994) Future directions in drug treatment of atherosclerosis. 8th Int. Dresden Symp. On Lipoproteins an Atherosclerosis. Abstracts. Dresden, June 10–12, 1994, 22

Page proofs will be sent to the authors for marking of printer's errors. Ten reprints will be sent, free of charge; to the principal authors.
Subscription rate: 20 USD (+postage) send to the editor.

ISSN 1406–9822