TARTU ÜLIKOOLI
TOIMETISED

УЧЕНЫЕ ЗАПИСКИ ТАРТУСКОГО УНИВЕРСИТЕТА

ACTA ET COMMENTATIONES UNIVERSITATIS TARTUENSIS

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BIOLOGICAL AND PEDAGOGICAL PROBLEMS OF PHYSICAL EDUCATION AND SPORT

Tõid kehakultuuri alalt

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CONTENTS

NEUROMUSCULAR ASPECTS OF FATIGUE INDUCED BY SUSTAINED SUBMAXIMAL STATIC CONTRACTIONS

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INTRODUCTION

A voluntary muscular contraction depends on a chain of events starting with an adequate input to the motor cortex and terminating with the energy - dependent interaction of actin and myosin. Failure of any of these events could result in the loss of force that characterizes fatigue. Muscular fatigue has often been defined as an inability to maintain the expected force or power output [1, 13, 66]. The decrease in contraction force may involve processes associated with the central command of contraction [5, 24, 46, 68] and with changes at the peripheral level [23, 27, 42, 48]. Moreover, the particular site or combination of sites that fails first may well depend on the type and intensity of muscular activity causing fatigue. Some possible sites of fatigue are: excitatory input to motor cortex, excitatory drive to lower motoneuron, motoneuron excitability, neuromuscular transmission, sarcolemma excitability, excitation — contraction coupling, contractile mechanism, metabolic energy supply [6, 13]. The command chain for voluntary muscular activity involves steps and force failure — that is, fatigue — can occur as a result of impairment at any one or more link in the chain of command. "Peripheral" and "central" fatigue may appear separately or combined depending on the specific situation. Any of the links in the long chain from the voluntary motor centers in the brain to the contractile filaments in the single muscle fibers may be the weaker and thus the most direct cause of muscle fatigue. Prevention and treatment of fatigue in voluntary muscular contraction must be adapted to the complexities [1].

Many everyday activities involve various forms of muscular activity with a static component. When one makes a sustained maximal static effort the force that can be developed starts to fall at once [4]. Static contractions at submaximal levels whether sustained or intermittent can be carried out at the same rate for some time before either the intensity or speed must be reduced [1, 13, 66]. In normal life muscles usually contract in response to less than maximal effort, often in a repetitive manner with a brief rest period between. The rate at which fatigue develops depends on the force generated, how long each contraction is held and the periods of rest between. The factors also determine the degree to which the blood supply is impeded and the rates of substrate utilization for energy supplies [18, 55]. The changes that appear throughout the neuromuscular system in relation to fatigue differ somewhat according to the type of exercise performed. These changes may also vary between the different sites of neuromuscular system employed depending on their function, architecture and muscle fibre type compositions. The impaired muscle function during human voluntary submaximal static contractions depends in numerous factors but the relative roles played by each are poorly understood.

The purpose of the present study was to examine the relationships between central motor drive, motoneuron excitability, excitation-contraction coupling and peripheral muscle contractile failure in repeated submaximal static contractions in humans sustained to exhaustion. Recordings were made from the quadriceps femoris muscle. Besides that specific features of muscle fatigue in power-trained and endurance-trained athletes as well as untrained subjects were observed. We aimed to investigate in pre-exercise and post-exercise conditions the values and relationships of selected neuromuscular performance variables including patellar reflex in normal and Jendrassik manoevre condition, maximal voluntary contraction and relaxation, electromyography (EMG), muscle stiffness(tone).

MATERIALS AND METHODS

Subjects. Three male groups were tested: (1) 15 sprinters and jumpers (power-trained athletes group), (2) 15 middle and long distance runners (endurance-trained athletes group) and (3) 15 volunteers normal healthy students (untrained subjects group). The physical characteristics of the three groups of subjects are presented in Table 1.

Apparatus. The subjects sat on a straight-backed dynamometer chair with the knee and hip angles equal to 90° and 110°, respectively. The force produced by isometric voluntary contractions of the right quadriceps femoris muscle was measured with a strain gauge. An inelastic strap was placed around the distal part of ankle above the malleoli and connected to the strain gauge. The output form the strain gauge was amplified and recorded in an oscillograph paper. The patellar reflex was measured when the subjects sat relaxed and

Table 1

Means (±SE) of the physical characteristics of the subject's groups

Group	n	Age (years)	Height (cm)	Weight (kg)
Power-athletes	15	23.3 ± 1.5	181.3 ± 1.2	75.4 ± 2.0
Endurance-athletes	15	21.1 ± 0.8	179.4 ± 1.7	67.4 ± 1.5
Untrained	15	22.5 ± 0.8	177.9 ± 1.7	71.8 ± 1.9

blindefolded on the dynamometer. Patellar tendon was tapped by special mechanical reflex hammer. An electrical goniometer was attached to the knee joints of the subjects to measure the knee extension during the patellar reflex. EMG activity was recorded from rectus femoris muscle during voluntary and reflex contractions using bipolar surface silver/silver chloride electrodes (10 mm contact area, 20 mm inter-electrode distance). Surface stimulation over the muscle was used to determine the position of its motor point. Before the electrodes were attached, the skin area was dry shaved and rubbed with alcohol and ether (4:1). The electrodes were prepared with electrode gel and placed parallel to the fibre axis and distal to the motor point. The reference electrode was attached to the distal part of the calf. The EMG signals were amplified using Medicor MG-42 preamplifiers and the EMG integrator. Muscle stiffness(tone) was measured in the region of the belly of rectus femoris muscle using an electro-myotonometer, constructed by Vain and Humal [63]. The EMG signals, reflex extension(angle) and force signals were simultaneously recorded on an oscillograph paper.

Calculation of maximal voluntary isometric contraction and relaxation characteristics. The subjects were instructed to react to the light signals (ignition of the lamp) as quickly and as strongly as possible by extending the leg against a cuff fixed to a strain-gauge system, to maintain the maximal effort as long as the signals were on (2s) and to relax the muscles suddenly after dissappearance of the signals. The force-time curve, EMG activity and light signal were recorded on the oscillograph paper as shown in Figure 1. The following data were calculated:

(1) latency of contraction (LAT_c,s) = time lag between the light signal and the onset of the EMG activity;

(2) electromechanical delay of contraction (EMD_c,s) = time interval between the beginning of EMG activity and the onset of force production;

(3) maximal voluntary contraction (MVC,N) was defined as the highest value of force recorded during the contraction;

(4) rate of force development (RF,N/s) was calculated by the

formula: RF $= F_{0.3}/0.3$, where $F_{0.3}$) is force after 0.3 s from the onset of contraction;

(5) latency of relaxation (LAT_r,s) = time lag between the turn off of the light signal and the onset of decrease of force (F_r) in the process of muscle relaxation;

(6) rate of relaxation (RR,N/s) was calculated by formula: RR $= F_r/\frac{1}{2}$ RT, where $\frac{1}{2}$ RT is half relaxation time.

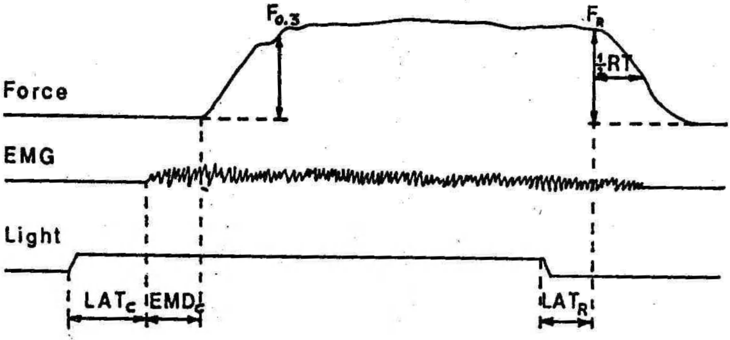

Figure 1. Schematic presentation of the records obtained in maximal voluntary contraction and relaxation measurements. LAT_c = latency of contraction; EMD_c = electromechanical delay; $F_{0.3}$ = force after 0.3 s from the onset of contraction; LAT_r = latency of relaxation; F_r = force at the moment of beginning of relaxation; $\frac{1}{2}$ RT = half-relaxation time.

Calculation of patellar reflex characteristics. EMG activity, tendon tap and knee extension(angle) in patellar reflex measurements were registered on the oscillograph paper as shown in Figure 2. The following characteristics were calculated:

(1) reflex electromechanical delay (EMD_R,s) = time interval between the beginning of EMG activity and onset of knee extension;

(2) peak-to-peak amplitude of reflex EMG activity (EMG_R,mV);

(3) peak amplitude of reflex knee extension (A_R, degrees) was calculated as the peak of the knee angle changes;

(4) ratio of reflex mechanical and EMG activity (A_R/EMG_R, degree/mV);

(5) increase of the amplitude of reflex EMG activity in condition of Jendrassik maneuver (Δ EMG_J,%).

For the reflex trials performed with a Jendrassik maneuver, the subjects extended an isometric contractions with their arms using a dynamometer with the load of 50 % MVC.

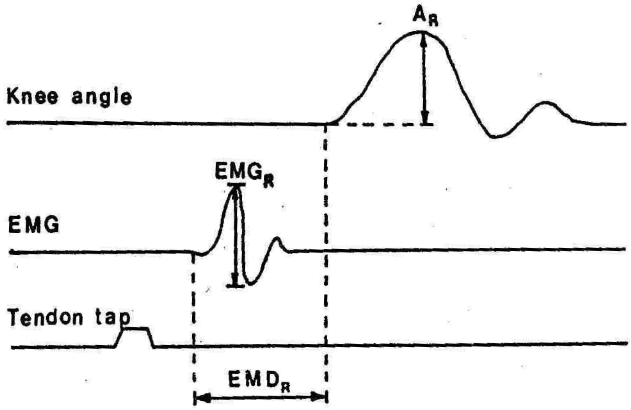

Figure 2. Schematic presentation of the records obtained in patellar reflex measurements. EMD_R = reflex electromechanical delay; EMG_R = peak-to-peak amplitude of reflex EMG response; F_R = peak of the knee extension.

Calculation of integrated EMG activity during the static exercise. The EMG integrated (IEMG for 1s,mV·s) used special EMG integrator from start to the end of each static contraction, maintained to exhaustion. IEMG was recorder on the oscillograph paper as shown in Figure 3. Medial IEMG activity was calculated during the first and final 5 s of each contraction.

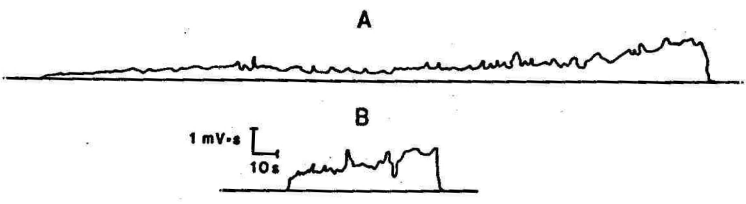

Figure 3. Typical record of IEMG activity from the rectus femoris muscle during the first (A) and tenth (B) static contraction till exhaustion.

Calculation of muscle stiffness. Stiffness of the rectus femoris muscle was calculated by the analysis of damped mechanical oscillations caused by a dosed impact on belly of relaxed muscle as shown in Figure 4. The variable for muscle stiffness was the frequency of oscillations calculated by formula: $v = 1/T$ (Hz), where T is the amplitude of oscillations(s).

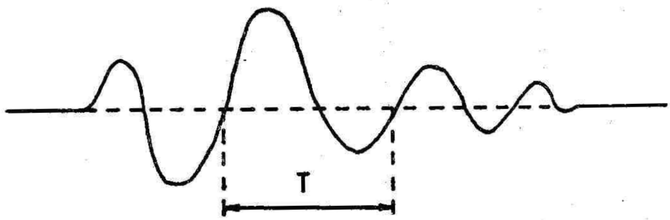

Figure 4. Schematic presentation of the records obtained in muscle stiffness measurements using the method of damped oscillations. T = period of oscillation.

Exercise. The exercise consisted of ten trials of the submaximal static contractions which were performed with the inter trial rest intervals of 1 min. The static contractions of the quadriceps femoris muscle were loaded with 40 % of the subject's MVC, and the subject was instructed to hold the contractions to the agreed end-point which was the failure to maintain the required tension (till exhaustion). The holding time for each contraction (T_c) and summarized holding time for all ten contractions (ΣT_c) were calculated.

Experimental protocol. Maximal voluntary contraction and relaxation, patellar reflex and muscle stiffness characteristics were recorded in pre-exercise condition, immediately after the 10th contraction to exhaustion, and during the recovery periods of 5, 10 and 15 min after the exercise. IEMG activity was registered during each contraction. At the beginning of inter trial rest periods muscle stiffness was recorded after each contraction.

Statistics. Standard statistical methods were used for the calculation of mean ($\bar{x}$), standard error of the mean (SE) and linear coefficient of correlation (r). The differences between the mean values were tested for significance by using Student's t-test. The probability level accepted for statistical significance was $P < 0.05$.

RESULTS

Pre-Exercise Condition

Maximal voluntary contraction and relaxation characteristics (see **Table 2**). The mean values of LAT_c ranged from 0.163 s to 0.170 s that agrees with findings of Vysotchin [67] under similar experimental conditions. The mean values of EMD_c ranged from 0.044 s to 0.047 s that were a little longer than data published by Ralston et al. [52] and Viitasalo [64]. The means of LAT_r were a little shorter than data

Table 2

Means (±SE) of maximal voluntary contraction and relaxation characteristics in pre-exercise condition

Variables	Group			Significance of differences P		
	Power-trained	Endurance trained	Untrained			
	1	2	3	1–2	1–3	2–3
LAT_c, s	0.163 ± 0.001	0.169 ± 0.006	0.170 ± 0.008	–	–	–
EMD_c, s	0.044 ± 0.002	0.047 ± 0.002	0.043 ± 0.002	–	–	–
MVC, N	563 ± 20	449 ± 17	514 ± 16	< 0.05	< 0.05	–
RF, N/s	1703 ± 67	1537 ± 67	1654 ± 65	< 0.05	< 0.05	–
LAT_r, s	0.158 ± 0.013	0.174 ± 0.013	0.150 ± 0.008	–	–	–
RR, N/s	6837 ± 857	6207 ± 869	6558 ± 666	–	–	–

published by Vysotchin [67]. No significant differences were found between LAT_c, EMD_c, LAT_r and RR of various groups. However, the power-trained athlete group had significantly ($P < 0.05$) greater MVC and RF than the other two groups. MVC had significant positive correlations with RF ($r = 0.78$, $P < 0.001$) and RR ($r = 0.55$, $P < 0.001$) and RF with RR ($r = 0.72$, $P < 0.001$).

Patellar reflex characteristics (see Table 3). No differences between the athletes groups and untrained groups were founded.

Table 3

Means (±SE) of patellar reflex characteristics in pre-exercise condition

Variables	Group		
	Power-trained	Endurance-trained	Untrained
$EMD_{R,s}$	0.075 ± 0.002	0.075 ± 0.002	0.071 ± 0.003
EMG_R, mV	0.63 ± 0.10	0.70 ± 0.06	0.73 ± 0.11
A_R, degree	16.1 ± 2.0	15.8 ± 1.9	19.0 ± 1.4
A_R/EMG_R	25.6 ± 3.9	22.6 ± 2.0	26.0 ± 4.3
ΔEMG_J, %	189.5 ± 50.3	148.1 ± 46.7	124.4 ± 32.0

Muscle stiffness (see Table 4). The endurance-trained athletes group had significantly grater muscle stiffness value in relaxed condition than the untrained subjects group. No differences between the athletes groups were found.

Table 4

Means (±SE) of muscle stiffness (v, Hz) in pre-exercise condition

Group			Significance of differences P		
Power-trained	Endurance-trained	Untrained			
1	2	3	1–2	1–3	2–3
9.8 ± 0.2	10.0 ± 0.1	9.4 ± 0.1	–	–	<0.05

Static Exercise Condition

Holding time. The holding time means for each static contraction (T_c) are depicted in Figure 5 and the means of summarized holding time for all ten contractions (ΣT_c) in Table 5. Holding time decreased rapidly after the first 2–3 trials followed by a steady state level with no further significant change (Fig. 5). A repeated measured analysis of variance showed that the endurance-trained athletes group had significantly longer holding times than the other groups for all ten trials. However, the endurance-trained athletes group demonstrated a large loss of holding time from trial 1 to trial 2.

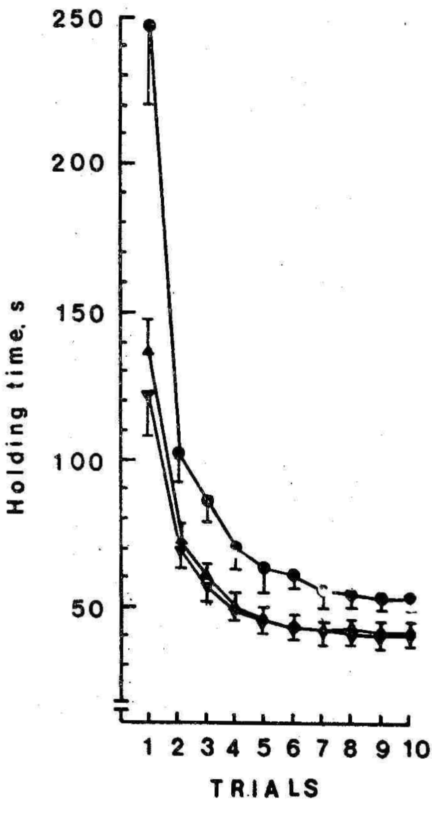

Figure 5. Holding time (mean ± SE) of ten static contractions for power-trained athletes (▼), endurance-trained athletes (•) and untrained subjects (▲).

IEMG activity (see Table 6). During each maintained contraction the amplitude of IEMG signals increased progressively. It was

Tabel 5

Means ($\pm$SE) of summarized holding time of ten static contractions (ΣT_c, s)

Group			Significance of differences P		
Power-trained	Endurance-trained	Untrained			
1	2	3	1–2	1–3	2–3
555.2 ± 39.1	845.9 ± 66.9	574.9 ± 29.3	<0.01	-	<0.1

significant for the first 3–4 trials. At the same time, the amplitude of IEMG recorded at the beginning of each contraction increased steeply and was at the beginning of the 10th trial 5–6 times higher than at the beginning of the 1st trial. The relative changes for power-trained athletes were meanly 484.1 ± 45.4 % ($P < 0.001$), endurance-trained athletes 568.5 ± 85.0 % ($P < 0.001$) and untrained subjects 557.6 ± 56.3 % ($P < 0.001$). IEMG activity recorded at the end of each contraction increased and was of the end of the 10th contraction 1.5–2 times higher than at the end of the 1st contraction. The relative changes for power-trained athletes were meanly 219.7 ± 20.7 % ($P < 0.01$), endurance-trained athletes 141.0 ± 14.0 % ($P < 0.05$) and untrained subjects 204.9 ± 19.4 % ($P < 0.001$) These changes were a more expressed for endurance-trained athletes than for the other two groups.

Muscle stiffness (see Table 7). During the static exercise the stiffness of quadriceps femoris muscle rapidly increased after the first 2–3 trials followed the steady state level. After the 10th trial the muscle stiffness relative change was for power-trained athletes group 126.9 ± 3.2 % ($P < 0.001$), endurance-trained athletes group 121.2 ± 1.9 % ($P < 0.001$) and untrained subjects group 123.0 ± 3.5 % ($P < 0.001$). A fifteen minute period was too snort for stiffness to demonstrate complete recovery. No significant differences between the dynamics of muscle stiffness between the groups were found.

Post-Exercise Condition

Maximal voluntary contraction and relaxation characteristics (see Table 8). No significant changes were seen in LAT_c and LAT_r after a static exercise while EMD_c increased by about 50 %. Fatigue effected decline in MVC, RF and RR. During a fifteen minute recovery period MVC and RR did not recover the prefatigue level.

Patellar reflex characteristics (see Table 9). Fatigue effected a

Table 6

Changes in IEMG activity (mV·s) during static contractions (mean ± SE, +-significantly different from 1st trial at P < 0.05)

Group	Trials	In the beginning of the contraction	In the end of the contraction	Significance of differences, P
Power-trained	1	0.15 ± 0.06	0.88 ± 0.09	< 0.001
	2	0.40 ± 0.06	1.01 ± 0.10	< 0.001
	3	$0.66 \pm 0.08^{+}$	1.11 ± 0.11	< 0.01
	4	$0.78 \pm 0.08^{+}$	$1.28 \pm 0.12^{+}$	< 0.01
	5	$0.92 \pm 0.09^{+}$	$1.40 \pm 0.15^{+}$	< 0.05
	6	$0.96 \pm 0.09^{+}$	$1.45 \pm 0.18^{+}$	< 0.05
	7	$1.06 \pm 0.08^{+}$	$1.41 \pm 0.17^{+}$	–
	8	$1.22 \pm 0.10^{+}$	$1.75 \pm 0.24^{+}$	–
	9	$1.22 \pm 0.08^{+}$	$1.68 \pm 0.20^{+}$	–
	10	$1.22 \pm 0.11^{+}$	$1.93 \pm 0.27^{+}$	–
Endurance-trained	1	0.19 ± 0.04	0.94 ± 0.12	< 0.001
	2	$0.51 \pm 0.09^{+}$	1.05 ± 0.14	< 0.01
	3	$0.72 \pm 0.10^{+}$	1.15 ± 0.17	< 0.05
	4	$0.86 \pm 0.11^{+}$	1.15 ± 0.15	–
	5	$0.89 \pm 0.13^{+}$	1.19 ± 0.13	–
	6	$1.08 \pm 0.16^{+}$	1.23 ± 0.12	–
	7	$1.02 \pm 0.14^{+}$	1.24 ± 0.14	–
	8	$1.04 \pm 0.16^{+}$	1.27 ± 0.14	–
	9	$0.99 \pm 0.13^{+}$	1.34 ± 0.14	–
	10	$1.06 \pm 0.16^{+}$	1.33 ± 0.13	–
Untrained	1	0.14 ± 0.03	0.47 ± 0.07	< 0.001
	2	$0.27 \pm 0.03^{+}$	0.57 ± 0.06	< 0.001
	3	$0.40 \pm 0.05^{+}$	0.64 ± 0.06	< 0.05
	4	$0.50 \pm 0.06^{+}$	$0.72 \pm 0.05^{+}$	< 0.05
	5	$0.57 \pm 0.06^{+}$	$0.72 \pm 0.07^{+}$	–
	6	$0.51 \pm 0.06^{+}$	$0.80 \pm 0.07^{+}$	–
	7	$0.66 \pm 0.07^{+}$	$0.83 \pm 0.07^{+}$	–
	8	$0.72 \pm 0.09^{+}$	$0.89 \pm 0.08^{+}$	–
	9	$0.77 \pm 0.08^{+}$	$0.88 \pm 0.08^{+}$	–
	10	$0.80 \pm 0.08^{+}$	$0.95 \pm 0.06^{+}$	–

prolongation in EMD_R and a decrease in EMG_R, A_R and A_R/EMG_R ratio. During a fifteen minute recovery period A_R and A_R/EMG_R ratio did not return to the pre-exercise level. The increase of ΔEMG_J was found immediately after the end of the static exercise. The recovery of EMG_R and ΔEMG_J was completed in five minutes. The change of all variables of patellar reflex after the static exercise were similar to all the groups.

Correlations of holding time and neuromuscular performance

Table 7

Relative changes (% initial value ± SE) in muscle stiffness after static contractions (+-significantly different from pre-exercise value at P < 0.05)

Moment of recording		Group		
		Power-trained	Endurance-trained	Untrained
After trials	1	$110.2 \pm 2.6^{+}$	$109.9 \pm 1.5^{+}$	$110.0 \pm 2.3^{+}$
	2	$118.1 \pm 4.0^{+}$	$113.8 \pm 1.7^{+}$	$114.7 \pm 2.3^{+}$
	3	$119.6 \pm 3.6^{+}$	$117.6 \pm 1.5^{+}$	$117.0 \pm 2.8^{+}$
	4	$120.6 \pm 3.4^{+}$	$118.4 \pm 1.5^{+}$	$118.7 \pm 2.5^{+}$
	5	$123.1 \pm 3.1^{+}$	$119.7 \pm 2.0^{+}$	$120.1 \pm 3.1^{+}$
	6	$123.0 \pm 3.3^{+}$	$120.0 \pm 1.6^{+}$	$121.4 \pm 3.0^{+}$
	7	$125.3 \pm 3.4^{+}$	$120.3 \pm 1.8^{+}$	$120.8 \pm 3.2^{+}$
	8	$125.2 \pm 3.6^{+}$	$120.9 \pm 2.0^{+}$	$122.1 \pm 3.6^{+}$
	9	$125.9 \pm 3.1^{+}$	$122.0 \pm 2.1^{+}$	$122.3 \pm 3.3^{+}$
	10	$126.9 \pm 3.2^{+}$	$121.2 \pm 1.9^{+}$	$123.0 \pm 3.5^{+}$
Recovery	5	$120.0 \pm 3.6^{+}$	$114.8 \pm 2.4^{+}$	$118.0 \pm 2.8^{+}$
	10	$116.7 \pm 3.5^{+}$	$113.6 \pm 3.3^{+}$	$115.5 \pm 2.5^{+}$
	15	$112.8 \pm 3.2^{+}$	$108.2 \pm 1.8^{+}$	$112.5 \pm 2.5^{+}$

variables. The correlation coefficients were calculated to assess the relationship of isometric holding time with the various neuromuscular variables of initial value. The correlation between T_c with the initial value of MVC, RF and RR were $r = -0.61$, $r = -0.49$ and $r = -0.35$ ($P < 0.05$, $n = 45$), respectively.

DISCUSSION

The present study demonstrates a gradual two phase decrease in endurance (holding) time of submaximal static contractions. During the first phase holding time decreased rapidly after the first two-three trials. The second phase is characterized by stabilization of holding time of static contractions on a lower level. Similar results were received by other investigators [13, 53, 60]. A decrease in holding time of submaximal static contractions can be explained by the failure of the central motor drive to adequately activate the muscle or by the failure of peripheral impulse propagation. In sustained contractions the causes of fatigue must be confirmed to the muscle itself [13, 18, 30, 42]. It is well known that in all contractions exceeding < 25 % MVC, the blood supply is severely restricted by the increased intramuscular pressure [2]. In this situation the energy must mainly be supplied by an anaerobic process. Accordingly,

Table 8

Relative changes (% initial value ± SE) in maximal voluntary contraction and relaxation characteristics after static exercise (+-significantly different from pre-exercise value at $P < 0.05$)

Variables	Recovery	Group		
		Power-trained	Endurance-trained	Untrained
	1	106.7 ± 6.7	98.2 ± 4.1	97.6 ± 6.5
	5	98.2 ± 8.0	89.9 ± 3.0	91.2 ± 5.3
LAT_c	10	94.5 ± 5.5	91.1 ± 5.3	88.2 ± 4.1
	15	89.6 ± 4.3	94.1 ± 4.1	92.4 ± 3.5
	1	156.3 ± 6.8+	144.7 ± 8.5+	155.8 ± 7.0+
	5	136.4 ± 9.1+	119.1 ± 4.3+	137.1 ± 7.0
EMD_c	10	127.3 ± 9.1+	112.8 ± 4.3	125.6 ± 7.0+
	15	120.5 ± 4.5+	110.6 ± 4.3	118.6 ± 7.0+
	1	59.1 ± 3.9+	70.0 ± 4.3+	61.9 ± 4.7+
	5	69.0 ± 4.3+	77.5 ± 4.7+	68.5 ± 5.5+
MVC	10	75.7 ± 4.3+	82.9 ± 4.1+	76.8 ± 5.9+
	15	78.6 ± 4.0+	87.1 ± 4.8	79.3 ± 5.8+
	1	57.9 ± 3.8+	63.4 ± 4.2+	56.8 ± 4.6+
	5	70.0 ± 4.7+	73.2 ± 5.5+	69.2 ± 5.4+
RF	10	74.7 ± 3.9+	74.7 ± 5.1+	73.3 ± 5.2+
	15	75.3 ± 4.0+	76.8 ± 4.8+	76.0 ± 5.9+
	1	108.9 ± 5.1	97.1 ± 5.2	110.0 ± 6.7
	5	99.4 ± 4.4	94.8 ± 4.0	105.3 ± 6.0
LAT_r	10	95.5 ± 5.1	91.4 ± 3.4	99.3 ± 5.3
	15	101.3 ± 7.0	95.4 ± 5.2	100.7 ± 5.3
	1	59.7 ± 6.1+	61.1 ± 5.8+	51.5 ± 6.1+
	5	78.7 ± 13.1	70.3 ± 7.5	69.4 ± 9.1+
RR	10	78.3 ± 10.2	72.2 ± 6.7	76.3 ± 11.1
	15	73.7 ± 8.8	72.5 ± 6.7	64.1 ± 7.3+

substantial substrate depletion and lactate accumulation with the fall in intramuscular pH have generally been observed [12, 18, 55].

Many studies indicate that during fatiguing exercises of various type may fail excitation-contraction coupling of active muscle fibres [21, 33, 37, 69]. For experimental investigation of excitation-contraction coupling of human muscle fibers electromechanical delay (EMD) was often used — time interval between the onset of EMG activity and mechanical response (force production) of muscular contraction [34, 35, 64]. Our studies indicated the significant increase of EMD both in reflex and voluntary contraction condition after fatiguing submaximal static contractions, i.e. There is a failure of

Table 9

Relative changes (% initial value ± SE) in patellar reflex characteristics after static exercise ($^{+}$-significantly different from pre-exercise value at $P < 0.05$)

Variables	Recovery, min	Group		
		Power-trained	Endurace-trained	Untrained
	1	140.0 ± 8.0^{+}	134.7 ± 4.0^{+}	125.4 ± 5.6^{+}
	5	128.0 ± 8.0^{+}	124.0 ± 4.0^{+}	116.9 ± 4.2^{+}
EMD_R	10	120.0 ± 5.3^{+}	116.0 ± 4.0^{+}	111.3 ± 4.2
	15	108.0 ± 2.7	110.0 ± 2.7^{+}	107.0 ± 2.8
	1	76.2 ± 12.7^{+}	77.1 ± 12.9^{+}	76.3 ± 13.7^{+}
	5	79.4 ± 14.3	75.7 ± 15.7	83.2 ± 15.1
EMG_R	10	76.2 ± 11.1^{+}	80.0 ± 12.9	106.9 ± 19.2
	15	85.7 ± 15.9	85.7 ± 17.1	91.8 ± 20.5
	1	26.6 ± 4.5^{+}	23.5 ± 5.3^{+}	27.5 ± 5.8^{+}
	5	25.3 ± 4.2^{+}	31.3 ± 7.2^{+}	34.5 ± 5,1^{+}
A_R	10	29.1 ± 5.7^{+}	35.6 ± 6.6^{+}	40.5 ± 6.7^{+}
	15	37.8 ± 5.4^{+}	34.0 ± 7.0^{+}	40.4 ± 6.5^{+}
	1	35.1 ± 3.6^{+}	30.4 ± 5.1^{+}	31.7 ± 5.0^{+}
	5	32.1 ± 6.6^{+}	41.0 ± 4.7^{+}	37.3 ± 6.8^{+}
A_R/EMG_R	10	38.3 ± 5.2^{+}	44.3 ± 4.9^{+}	37.9 ± 6.8^{+}
	15	44.1 ± 6.2^{+}	39.9 ± 4.8^{+}	44.1 ± 7.0^{+}
	1	149.1 ± 18.9^{+}	201.6 ± 51.7^{+}	212.1 ± 49.7^{+}
	5	135.8 ± 25.1	161.4 ± 50.6	114.6 ± 26.0
EMG_J	10	135.8 ± 28.4	151.0 ± 45.9	94.2 ± 28.0
	15	157.4 ± 37.1	134.5 ± 39.2	90.8 ± 28.5

excitation — contraction coupling in active muscle fibers. There was indicated a failure of conduction of action potential along the muscle fibers and into the T-system after fatiguing contractions [36]. Accumulation of lactate in fatiguing muscle fibers has been shown to decrease intramuscular pH [43, 54] which has been though to reduce the capacity of sarcoplasmic reticulum to release and uptake Ca^{2+} [10, 58] and a failure of cross-bridge formation which causes the slowing of force production. These factors are the possible causes of the increase of electromechanical delay after a static exercise.

Our results showed the decrease of MVC as well as rates of voluntary force production and voluntary relaxation after fatiguing submaximal static contractions. The rather rapid decline in the maximal force production of voluntary muscle contraction observed during fatigue involves both "central" and "peripheral" factors. The "central" factor includes the failure of production of the available total motor unit pool recruited and motoneuron excitability during contraction [44, 45]. As was shown by Bigland-Ritchie et al. [7] during 50 % MVC submaximal isometric contractions of the quadriceps femoris muscle the decreased force-generating capacity could not be explained by the lack of central motor drive. The mechanism responsible must therefore be located in the muscle itself. During all sustained contractions large biochemical changes have been observed [18, 55]. Almost total depletion of creatine phosphate store has been reported as well as a profound increase in the muscular lactate concentration. Thus a decrease of muscle strength has been attributed to low substrate availability and a decrease in pH from lactacidosis [66].

The rate of voluntary muscle relaxation was sensitive to fatigue in our experiments. Thus some neural mechanisms are assumed to be responsible for the slowing down of relaxation during fatigue together with the slowing down of relaxation of individual motor units. At the motor unit level the reason for the change of mechanograms during fatigue was probably the change of intramuscular lactate and pH which in turn may inhibit resynthesis of ATP. The diminished amount of ATP may have slowed the function of Ca^{2+} pump, removal of Ca^{2+} from contractile material and as a result of this, the relaxation of motor units took more time.

During sustained submaximal voluntary contractions the required force may be achieved by alterations in motor neurone drive, i.e. by increasing the impulse frequency and/or the number of motor unit recruited [19, 28, 40, 50]. Evidence to that such competition occurs is the observed increase in the IEMG activity for the given force in our experiments. There was a tendency of IEMG activity to increase with successive trials as well as of the end of each sustained contraction. The recruitment and synchronization/firing factors may effect the IEMG activity during submaximal contractions. There are several reports in the literature indicating an increase in IEMG or mean voltage [19, 50, 65].

Variables which enable indirectly to assess the general nervous processes — excitability and inhibition — in the higher centers of the central nervous system (CNS) are the latency of voluntary muscular contraction and the latency of voluntary relaxation. It is known that the latency of voluntary muscular contraction indicates the speed of origin and propagation of the excitability in the reflex arc. i.e. motor cortex impulsation [15, 16, 25]. The latency of voluntary relaxation indicates the speed of origin and propagation of the inhibition in CNS [15]. Our experiments indicated no significant changes in the latency of voluntary contraction and relaxation of active muscle after static exercises. These findings are in general agreement with the results published by Kroll [37] and Martyanov et al. [41] who observed no changes in reaction time variables, i.e. any inhibition in higher centers on CNS after various static contractions.

Our data indicated the origin of inhibition in spinal motor centers after a static exercise. This conclusion is supported by the decrease in patellar reflex EMG response immediately after a static exercise. It is well known that the amplitude of the tendon jerk bioelectrical response is one of the variables indicating the step of reflex excitability of the spinal motor pool and the fascilitation of this response by Jendrassik maneuver characterizes the reflex excitability of spinal interneurones [20, 38]. There are some possible causes that induce the reduction of the reflex excitability of alpha-motoneurones after a physical exercise: reduction of the alpha-motoneurone fascilitation by supraspinal structures, i.e. a decrease in the cerebral influence to the motor neuron pool [39, 59]; activation of the interneurones which participate in the recurrent inhibition process [32, 47]; activation of some inter-spinal inhibitions systems [47]. Our data indicated a significant increase of the patellar reflex EMG response in condition of Jendrassik maneuver, i.e. an increase of the spinal interneurone reflex excitability after a static exercise. As shown by Clare and Landau [8], the gamma loop is not a significant part of the pathway for reflex reinforcement by the Jewndrassik maneuver. One of the possible mechanisms of this spinal interneurone fascilitation is the supraspinal influences. The present study indicated the increase of the stiffness of active muscle recorded in relaxed condition (muscle tone) after static contractions. One of the possible causes of this phenomenon is the increase of the volume of extremity which can take place by increasing the volume of the intramuscular fluid. The change of the osmotic pressure in individual muscle fibres as well as post-activity byperaemia after an exercise are possible [49, 61]. The relationship between the increase of the muscle stiffness after local muscular contractions and post-activity hyperaemia are indicated in our earlier reports [51].

Our data indicated a higher ability of endurance-trained athletes to maintain the submaximal static contractions in comparison with power-trained athletes and untrained subjects. One of the possible causes may be the training factor. It is well known that during the systematic endurance training slow twitch muscle fibers with relatively low force production are generally active. Endurance training causes the so-called sarcoplasmic type of hyperthrophy expressed by increase in the amount of mitochondrial proteins, glycogen. creatine phosphate, myoglobin [3, 9, 17]. As indicated by T. Seene et al. [56, 57] aerobic training causes an increase of the biosynthesis of myosin, specially an increase of a meromyosin in slow twitch muscle fibers. It is well known that endurance training causes a significant capillarisation of the muscle fibers. All these factors can increase the possibility of prolonged muscle work. The second factor which can influence the ability to maintain the muscular contractions is the genetically determinated muscle composition, i.e. the relationship between the number of the fast and slow twitch muscle fibers.

It has been demonstrated that static endurance at the level of 50 % of MVC is positively correlated with the percentage of slow twitch muscle fibers [22]. Since the blood flow at tensions corresponding to 50 % MVC is severely restricted with no or very little oxygen dilivery to the contracting fibres [14], the anaerobic glycolysis will be utilized for ATP resynthesis [29]. Isometric tensions corresponding to 30–50 % of MVC have been shown to produce maximal values for muscle lactate concentrations at the point of muscular exhaustion [30, 31]. Nonrecruited slow twitch fibres are one very probable recipient of released lactate. In addition, slow twitch fibres may be able to metabolize lactate formed in fast twitch fibres [22, 31]. Moreover, slow twitch fibres have been shown to contain larger amounts of myoglobin than fast twitch fibres [26]. There are many investigations which indicate the high percentage of slow twitch muscle fibers in *vastus lateralis* muscle of the endurance-trained athletes [11, 17, 62].

Therefore, the differences in relation to the ability to perform submaximal static work between the various groups of subjects can be connected both with the genetically determinated muscle composition and the morpho-functional adaptational changes in muscles caused by systematic training.

CONCLUSIONS

1. In condition of the repeated submaximal static contractions peripheral or muscle fatigue was expressed in reduction of the speed of transformation of the neural transmission to the contraction process and by the failure of the contractile properties of the active muscle fibers.

2. No significant changes of the reaction time variables — latency of the voluntary muscular contraction and relaxation — were found. This fact indicates the relative functional stability of the higher centers of the central nervous system under these conditions of muscle activity.

3. The reduction of the alpha-motoneurone reflex excitability was found after the static exercise tested by monosynaptic (patellar) reflex. This fact indicates the important role played by inhibition advanced in the spinal motor centers in the genesis of fatigue under these conditions. The spinal interneurone reflex excitability increased after a static exercise.

4. Endurance-trained athletes had a significantly higher ability to maintain the supramaximal static contractions in comparison with power-trained athletes and untrained subjects.

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4

PHYSICAL ACTIVITIES IN SERVICE OF IMPROVING THE HEALTH OF WOMEN AND GIRLS AND RAISING THEIR WORK ABILITY

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Numerous investigations have shown the positive influence of regular physical exercises on health [1, 9, 10, 11, 13, 14, 15, 16, 18] on the ability to do mental work and to learn [2, 3, 6, 7, 8, 12, 15, 17, 19] of both pupils and workers. It would be reasonable to suppose remarkable increase of the physical activity of people nowadays. This is not so. Just the opposite, results obtained by R. Silla [15, 16] show very bad physical condition of both children and adults. There are a lot of illnesses of heart and bloodvessel system that get started in the childhood. The main reason for this is the unhealthy way of life including chronical insufficient physical activity. The last is typical of 35 % of children of the pre-school age, 50 % of the junior, 60 % of the medium and 75–80 % of the senior school-age [15].

A very serious problem in Estonia is the health of young mothers, its influence on newborns, on youth and on all the nation. The health of a child during the first year depends 80 % on the health of the mother during gravity. The health of youth depends very much on the health of children in the first years of life. According to the data by L. Zagolski [20] 30 % of the women that gave birth to their children in 1986 in Moscow were ill. Ill mother means an "ill" child will be born [15, 20]. Most of the health problems of the children are caused by lowered moving activity. This shows that physical education as an important part of human life has not found a proper place in the system of values. It is not easy to change life style and the system of values.

Experience shows that full knowledge of the importance of physical activity is not enough to make the human to change the usual way of life, give up bad habits and start doing physical exercises. These changes need self-forcing, overcoming of lazyness, etc. Often people do not have enough will to do it [1, 10, 18].

It is necessary that somebody help these people to overcome the psychological barriers and sometimes would even force one to act.

The main aim of this work was to strengthen the health of women as well as girls of the age between 4 and 8 through regular physical activity, to raise their work ability and to help the girls to achieve healthy living habits.

The paper consists of two parts. The first gives a review of the investigations having been carried out in the V. Klementi Sewing Combine for 7 years. The aim of the study was to find ways to raise the effect of the physical exercises during work pauses and this way to improve the health of the workers, to increase their work ability and to form healthy life style. The work was carried out mostly by Assistant Professor S. Oja, Senior Instructors A. Oja and T. Sikkut and Senior Laboratory Assistant E. Rünk, the team being headed by S. Oja.

The second part of the paper contains materials on the physical activities of girls from 4 to 8 years old at the Tallinn Central Children Clinics. The research involved many medical doctors and trainers. The paper presents data collected by the author.

1. THE ROLE OF WORK GYMNASTICS IN IMPROVING THE STATE OF HEALTH AND WORK ABILITY OF FEMALE WORKERS

One of the basic methods of organizing physical exercises for many people is work gymnastics. It has repeatedly shown its fitness and efficiency in improving health, work ability and labour discipline of the workers [10, 11]. However, in spite of numerous resolutions to provide the necessary bodily exercises at the places of work, these activities are often neglected. Therefore, there are many hidden reserves to be found and applied to organize work gymnastics to gain the wished improvement of health of the nation.

Since April 1959 regular work gymnastics has been carried out in the V. Klementi Sewing Combine. Yet, the workers being ill relatively often, changes in work intensity, new machinery and more complicated tasks made it necessary to change the way the work gymnastics is done. To find out a rational daily schedule and work gymnastics cooperation was started in 1980 with the group of sports psychology at Tartu University. It lasted till the end of 1986. Special attention was devoted to work gymnastics as an active rest within the working day. It was obligatory for everybody. The way the work gymnastics is done can easily be checked and influenced by the leaders of the combine. It was presumed that well planned and provided work gymnastics would ensure systematic minimum of physical activities for the workers and therefore would have positive influence on their health and work efficiency.

1.1. The situation of the work gymnastics, physical abilities of the workers and their becoming exhausted during the working day at the beginning of the research work

According to the results of the way the work gymnastics was done, interviews with workers, data of psychological and physiological tests, daily curve of tiredness, work ability of the workers, data on illnesses, blood pressure, etc., the following can be said:

- physical activity of the workers was low and their understanding of the need of doing exercises missing;
- the time of the pause for exercise was not reasonable, the exercises did not fit the specific features of the work done. Only $\frac{2}{3}$ of the workers participated (half of them not seriously), the others either working, sitting, talking or having left the room. There were often complaints about health (heart disorder, ache in body, ishias), in many cases blood pressure was low (100 mm Hg or less) or high (over 160 mm Hg);
- veloergometric study showed low work ability;
- 60 % of the workers complained of being tired in the second half of day. This could also be seen from both objective and subjective parameters. The above mentioned complaints served as a reason for many workers for not doing the exercises.

1.2. The corrections in the work gymnastics and their influence on the health and work ability of the workers

1.2.1. Reasonable daily Schedule

To find out a reasonable daily schedule different possible schedules were compared in a pedagogical experiment. The results demonstrated that most resonable was to have one main (8–10 minutes) and two short (2–3 minutes) pauses for exercises. The short ones were proposed to take place at the working place, the longer pause — in the gym-hall.

The analysis of the experiment demonstrated clearly that many objective and subjective factors have to be considered in order to reach the reasonable schedule. We started with the one-pause schedule with the following corrections introduced at once:

- time of the pause was changed according to the daily curve of tiredness;
- different sets of exercises corresponding to the specific features of the work were introducted;
- better control doing the exercises was started;

— basic positions of different exercises were taught to the workers thoroughly;
— a series of lectures and discussions was provided, to improve the understanding of the people in the need of physical activity better.

At the same time preparations were made for transition to the three pause day. During the preparations more lectures on the need of physical exercises were provided over the radio as well as by lecturers. Psychological suggestions were also used to help the people to overcome barriers in their mind.

1.2.2. Psychological barriers and ways to overcome them

The main barriers people had were the following.

1. Low level of understanding of the need of physical exercises, of functioning of human body and the relations his between health and physical activities.

2. Numerous health problems (complaints on ishias and heart disorder) and devining from it the fear to damage one's health even more by doing the exercises.

3. Negative attitude to any physical exercises in general caused by different factors.

4. Clumsiness resulting from in experience and as a result, shyness (mostly fear of remarks or laugh).

5. Laziness, unwillingness to strain oneself, fear of becoming tired.

The following principles of social psychology were used to fight the barriers.

1. Patience and regular work is needed to be successful in influencing people. Forcing may cause harm instead of leringing success.

2. Small concessions at the beginning make it easier to achieve full demands. It is reasonable to allow somebody with strong negative attitude to start from some small movements. Full exercises can be demanded only later. It makes no sense to demand correct performance of full exercise from somebody fighting the fear to stand up.

3.You can never ashame a person even if one's knowledge is awfully low.

4. The level of knowledge is musch easier to raise if a person has interest in the problem. To create interest explanations have to be understandable and emotional.

5. While explaining the need to do physical exercises it is sometimes useful to cite well-known authors or bring them as an example.

6. If the negative attitude is very strong and hard to overcome

it makes sense to tell the person to stop his activities for a while. He then feels oneself not fulfilling orders but deciding by himself. And if the exercises are chosen well and seem useful for the person he may soon become an active advocate of them.

7. It is reasonable to find a way to everyone and to achieve trust. Quite often it was enough just to listen to the problems a person had. If you have achieved trustful relations then people agree to "be nice" and do exercises they do not like at first.

8. In communication it is needed to consider specific features of emotions, especially their subjective character, conditioned reflexes and an easy transfer of negative emotions to others.

9. Novelty, operative feedback of information, availability of medical check-up, comfort (i.e. possibility to do exercises in a well-eit gym), etc, will also have a positive influence on getting the people involved.

Taking into consideration the above-mentioned principles gave very good results and made the goals much easier to achieve. The problems of material basis, equipment, organisation of work (change of lunch-time and habitual daily schedule) were relatively easy to overcome. To overcome the psychological barriers demanded long and consequent work that lasted almost all the period of co-operation.

1.3. Increasing the level of knowledge of workers

A series of lectures over the local radio was provided to increase the level of knowledge of workers and their attitude to the physical exercises. Numerous individual and group talks were also conducted. Several written materials were compiled and distributed as well. We tried to explain that physical exercises cannot be taken as a favourite hobby but is something badly needed for a person's health. Workers liked personal or small group talks best. During them people felt free to ask questions and express their points of view. This work demanded a lot of time and patience but helped to reach the result more quickly.

The following topics were considered to be most interesting: "The role of physical exercises in strengthening health", "Relations of low physical activity and health problems", "The influence of long and short-term low physical activities on work ability and health", "The most suitable physical exercises", etc.

1.4. Transition to three physical exercise pauses

In the spring of 1982 the transition to three pauses a day was started and in the fall of that year all the combine used such daily schedule. All three pauses were fullfilled with exercises performed the working places under the accompaniment of music. Since spring of 1984 the exercises in the main factory of the combine in Tallinn are provided in a big hall during the main pause. The brigades visit the hall one after other to do exercises under the accompaniment of music and to the instructions of a trainer. It gives the workers a possibility to leave the working place for 10 minutes and fulfill the pause in a physically active way in fresh air.

1.5. Changes of the physical activity and health situation

1.5.1. Increase of the physical activity based on participation in work gymnastics

From year to year the total amount of workers regularily doing work gymnastics has increased (Table 1). The exercises were considered to be well done by those who did them actively and tried hard.

Table 1

The percentage of workers participating in work gymnastics

Year	Doing the exercises			
	Regularly	Incl. well	Irregularly	Not doing
1978	35.0		25.5	39.5
(data by M. Pavelson and E. Kuuli)				
1981	66.0	50.0	9.0	25.0
1982	80.0	70.0	7.0	13.0
1983	87.0	72.0	2.0	11.0
1984	89.0	83.0	3.0	8.0
1985	92.0	85.0	3.0	5.0

The main reasons for not doing the gymnastics in 1984 were being handicapped, not feeling well, etc.

1.5.2. Changes of the health situation of the workers during application of the work gymnastics

1.5.2.1. How did the workers feel themselves and their work ability

In 1981 60 % of the investigated workers said they felt very tired at the end of the working day, in 1982 the percentage was 40 %, in 1983 23 %, in 1984 12 % and in 1985 8 %. The same could also be seen from the results of psychological and physiological tests.

From year to year the range of variability of maximum blood pressure decreased (Table 2).

Table 2

Distribution of people investigated according to variability of maximum blood pressure during the working day (%).

Variability of maximum blood pressure mm Hg	Year		
	1980	1982	1983
0 – 10	52	61	68
11 – 20	36	34	30
21 – 30	8	5	2
31 – 40	4	0	0

Analysis of the maximum blood pressure in the morning demonstrated normalisation of the blood pressure and decrease of the number of those with very low (below 100 mm Hg) or high (over 151 mm Hg) pressure (Table 3). Measurements of blood pressure were not carried out during last years.

Table 3

Distribution of the maximum blood pressure in the morning (%)

Maximum blood pressure mm Hg	Year		
	1980 XII	1982 III	1983 XI
up to 100	9	5	2
101 – 110	13	13	13
111 – 120	29	32	38
121 – 130	23	35	35
131 – 140	10	8	10
141 – 150	8	4	2
151 and more	8	3	0

1.5.2.2. Illnesses of the workers

According to the data of the medical service of the combine the total amount of illnesses decreased during the experiment. The amount of days being ill decreased from year to year: in 1983 1240.5 days per year per 100 workers, in 1984 1167.9, in 1985 1094.1 and in 1986 1029.6. The total amount of illnesses in the main factory in Tallinn in 1986 was 23.4 % lower than that in 1983.

1.5.3. Conclusions

Summarizing the results of the seven years work we can say that constant social psychological work done with the dressmakers increased remarkably their physical activity, health and interest in doing exercises. An important role in the change of attitude to physical exercises was played by a permanent improvement of feeling and health, a decrease of being nervous and depressed and an increase of work ability. Remarkable positive changes were also noted in the usage of working time. From year to year the ratio of high-productive work increased. Many workers got involved in additional physical activities in addition to work gymnastics, often together with their children.

2. THE INFLUENCE OF SYSTEMATIC PHYSICAL ACTIVITIES ON PSYCHOLOGY AND PSYCHOMOTORICS OF GIRLS

The amount of children born absolutely healthy is diminishing permanently. More and more often children need medical help from the very birth.

The data of the Tallinn Central Children Clinics show that the health situation of children in Tallinn is bad. Most of the investigated 360 4 to 12 year-old children suffered from lowered respiratory function. Parameters of physical work ability (PWC_{170} by veloergometric test) varied from 42.4 to 55.7 % of that normal for the age. Remarkably has also increased the amount of adipose children, of those suffering from scoliosis and other illnesses [9]. Physical activity of children is relatively low and the attitude of parents to physical exercises is often not positive. Considering the above mentioned a group of specialists in physical education and doctors realised that it is not enough only to talk about the importance of physical exercises. To achieve a real positive effect we should start doing exercises with small girls and to make a healthy way of life for them a normal habit. One could hope that they will grow up healthy and active mothers, will give birth to healthy children and relying on their personal experience will direct their children to better physical and mental development.

The aim of this research was to study the influence of complex physical activities on psychomotorics and mental processes of the 4 to 7 year-old girls.

2.1. Methods

The research was carried out in January, April and December 1988, and in March-April 1989. All together 28 girls of 4–5 and

25 girls of 6–7 years participating in the groups of complex physical activities were investigated. Complex activities meant practical physical exercises (swimming, gymnastics with music and playing outdoor) and playing computer games.

During the study period the behaviour and acting of the children during the practical lessons, medical investigation, talks, etc. was observed. Conversations with both children and their parents were carried out many times.

In the computer lessons several simple games were used, demanding and developing mostly attention, ability to share attention between different activities and to correlate hand movements with the direction and speed of the objects moving on the screen. Several special tasks of developing reaction speed were also used. To develop creativity of children they were let to "drew" freely using different lines and shapes.

The choice of the research methods was made from the supposition that the tasks and activities should be easy to carry out, informative enough in relatively short time, suitable for children of different ages and usable in repeated research, interesting for children and activating them and provide the possibility of objective estimation.

Therefore we measured maximum speed of both left and right hand simple and complex movements, reaction to moving objects, exactness and sharing of attention between different activities.

The maximum speed of hand movement was fixed using a tremor. The experiment consisted of four series, 10 seconds each, with 15–20 second breaks between the series. The task was to make a maximum amount of contacts with an electric pencil, in the first series with right hand to one spot, in the second with left hand to one spot, in the third with right hand alternatively to two separate spots placed 5 cm from each other, and in the fourth with left hand to the two spots. The number of contacts in each series was fixed.

The reaction to moving objects was measured on the personal computer. The task was to stop a moving "man" on the screen at a certain point. Every child did it for 40 times, the number of exact attempts and range of mistakes in arbitrary units were fixed.

Attention, coordination and ability to learn them were studied using a game "UFO and balls". The task was to follow the "UFO" moving to the left and right on the screen, to hit it with the balls and to catch the balls thrown from the "UFO". We fixed: the number of balls thrown towards the "UFO" (a), the number of balls that hit the object (b), the number of balls falling from the object (c) and how many of them were caught (d). Two relations were calculated afterwards, showing success in hitting (100*b/a) and catching (100*c/d). The children had the possibility to decide how to act, whether to use one, two or three keys, to concentrate on some parts of the task or to try to do all at once.

Research was carried out in a specially equipped separate room. Before doing the experiment the attention of children was draven to the task. Positive reaction was used both before and after the task to increase the childrens self-assurdness and willinness to do the work.

2.2 Results and analysis

2.2.1. Maximum speed of movements

Table 4

Maximum hand movement speed — mean number of contacts in ten seconds at the beginning (I) and at the end of the experiment (III)

Age yr	n		Simple movements				Complex movements			
			Left		Right		Left		Right	
			x	σ	x	σ	x	σ	x	σ
4–5	24	I	33.4	0.98	29.2	0.82	24.2	1.07	19.9	0.65
		III	39.3	0.92	36.7	0.49	28.9	0.56	24.9	0.88
6–7	25	I	43.1	1.22	39.3	1.11	32.2	1.17	27.9	1.08
		III	48.3	1.09	45.4	1.06	35.3	0.85	31.8	1.46

n — the number of girls in the group, x — arithmetic mean, σ — standard error (here and in all the following Tables).

Maximum rate of movements (Table 4) demonstrated clearly some general features:

- for both groups simple movements are clearly quicker than complex ones ($p < 0.05$);
- for both simple and complex movements the right hand is much quicker than the left one ($p < 0.05$);
- both simple and complex movements become quicker with age ($p < 0.05$).

These data support our earlier investigations [21, 22].

Comparing the maximums fixed at the beginning and at the end of the experiment we see an increase for both simple and complex movements in both groups. This is probably a result of complex activities as well as due to change of the age of the children.

It must be mentioned that exept the increase of the speed during the last measurements the movements of the children were also much more exact. The number of missing the spot during the complex movements was much lower at the end of the experiment compared to what could be seen during the first measurements. Hands were less strained, not so spasmodical and there were less mistakes caused by the hand being too strained. Children did not complain of being very tired any more (especially those 4–5 years old). These data show that due to complex physical activities the ability to direct hand movements increased and it had also a positive influence on the exactness of the movements.

2.2.2. Reaction to moving objects

The data are presented in Table 5. Analysis of the data shows that older girls were much more exact compared to the younger ones. In both first and last measurement the percentage of exact attempts is higher for them than it is for the 4–5 year olds. For both groups the last measurement shows much better results than the first one. It is doubtless by due to the children becoming older, but also due to complex training. It must be added that the results showed clearly that for those girls who took part in the training more actively and were less absent the increase of exactness in much bigger.

Table 5

Reaction to moving objects before (I) and at the end (III) of the experiment

Age yr	n		Total number (Σ) and portion (%) of attempts Mistake in arbitrari units									
			Exact		1–5		6–10		11–15		16 and more	
			Σ	%	Σ	%	Σ	%	Σ	%	Σ	%
4–5	24	I	72	7.5	96	10.0	216	22.5	240	25.0	336	35.0
		III	120	12.5	168	17.5	240	25.0	192	20.0	240	25.0
6–7	25	I	140	14.0	190	19.0	327	32.7	163	16.3	180	18.0
		III	175	17.5	230	23.0	370	37.0	125	12.5	100	10.0

2.2.3. Results of the "UFO and balls" experiment

Results are presented in Table 6.

It must be mentioned that during the first measurements the task caused specific difficulties for 4–5 year old girls. They were in great trouble in timing their action. Sharing of attention between different activities was also hard for them and the measurements could be carried out with them only after a one month training and getting familiar with the computer.

In both groups there were very big differences in the success to fulfill the task. During the first experiments in both groups there were many children who paid no attention to different objects and

Table 6

Mean results at the beginning (I) and at the end (III) of the experiment

Age yr	n		Number of balls from up			Number of balls from down		
			x	σ	% of exact	x	σ	% of exact
4–5	24	I	642.1	108.8	3.2	177.3	18.3	4.7
		III	420.3	49.7	9.4	148.0	15.1	8.4
6–7	25	I	225.2	18.5	15.2	141.5	10.2	6.7
		III	190.3	10.4	27.0	151.2	8.5	14.6

pressed only a key to throw balls. During the last experiments they had become much more attentive and managed to direct their actions quite well. Comparing the data from the different rows of Table 6 we can seen that for both groups the results of the last measurement are much better than those of the first. Even more, every child had much better results in the last measurement than she had had in the first. The data demonstrate clearly the differences between the ability to share attention. The 6–7 year old girls have paid more or less equal attention to both sides of the task while the younger girls have paid much more attention to one of the sides and fulfilled it much better than the other one.

All the children liked the computer activities, both training and measurements very much. During the training they had the possibility to play different games within half an hour, to "draw", etc. A child could do different things depending on her own wish and choosing the speed suitable for her.

2.2.4. Pedagogical observations and conversations with parents and children

The parents were talked to mostly in personal consultations. Children were talked to and observed in different situations.

The results of the talks demonstrated that the parents were worried about their children and ready to contribute to their health and development. They also were ready to participate together with their children in different activities. Parents are often afraid that due to the lack of knowledge and experience they do not manage to do everything. The typical wishes of the parents were that their child should be intelligent, clever, nice, mobile, healthy, obedient, exemplary, etc. As children do not always fit the dream of their parents problems do occur. Many times parents complained that the child was very shy, cowardly, careless, nervous, capricious, disquiet, cried often, agressive, beating, throwing and crashing things, obstinate, etc. It appeared quit often that the disadvantages of the children were caused by the parents or the situation at home. The following could be mentioned:

— parents themselves are very nervous, overloaded, short of time, have too much to do, disgusted and tired;
— there is too little space to live in;
— there is a contradiction between the demands of the parents and the grandparents;
— the demands do not fit the age of the child. She always has to be the best, most beautiful, most clever, most careful, etc.;
— low level of demands has suddenly been changed to high;
— too much or too little attention to the child, overcare, doing everything instead of the child or vice versa, leaving the child or her own;
— jealousness of the child caused by the appearence of a brother or sister to the family or appearance of a new father or mother;
— the child is too overloaded, participates in too many activities, is overtired and inactive.

In the conversations advice was given to the parents and many of them were ready to consider it.

Conversations with the children showed clearly that almost all the children were normally developed, willing to act, with behaviour fitting the age, but with big personal variability. Based on the pedagogical observation it could be said that during the year of the experiment the children changed a lot, they became much more independent and bold, more self-assured and more disciplined. Reaction to oral commands was at the end of the experimental period almost momental both in the lessons of physical education and during any other activities. C. McCromick [4], A. Munrow [5], E. Peebo [12], S. Oja and E. Peebo [22], R. Silla [23] and others have also shown the positive influence of physical activities upon the self-control of children, upon their courage, creativeness, independence, etc. It must be mentioned that during the period remarkable changes also occurred in the physical conditions of the children. The children became more skilful, with more exact and coordinated movements.

The conversations with the parents during the experiment and after it showed the following:

— the parents were very satisfied with the complex activities as these resulted in their children becoming more self-assured, more courageous and quiet, more skilful;
— the health of the children had improved much during the year. If earlier a child had often been ill, then during the year it happened only once or even didn't happen at all (this was underlined by

66.7 % of the parents). In four cases the child had been very often and very seriuosly ill earlier;
— the parents appreciated swimming, gymnastics and the computer lessons especially highly. Unfortunately they did not understand as well the importance of the outdoor lessons. It was found that the children can play outdoors anyway, but it is much more complicted to find the possibilities to swim, go in for gymnastics or play on the computer. Although half of the parents could also see the importance of the outdoors lessons.

Summarizing the materials of the second part of the paper we could underline the following:
— the complex activities had positive influence to both physical and mental abilities of the children;
— the longer and more regular the participation of a child in the complex activities was the more clear were the positive changes of all the parameters investigated;
— during the experimental period the attention of the children and their ability to concentrate increased, as well as the ability to time different actions;
— the reaction of children to moving objects became more exact and the speed of small movements increased mostly due to remarkable decrease of general strain and that of the hand.

The health of children also became better during the period of the analysis [6].

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LACTATE THRESHOLD AS A CRITERION OF RUNNING TRAINING INTENSITY FOR UNTRAINED UNIVERSITY STUDENTS

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INTRODUCTION

At a certain level of exercise intensity the lactate production rate exceeds it elimination rate, leading to the accumulation of lactate in blood [6, 46]. The onset of blood lactate accumulation [30] or anaerobic threshold [36, 46, 50, 51] indicates the exercise intensity above what the oxidative phosphorylation is supplemented by increasing amount of anaerobic glycogenolysis in energy production of working muscles. Naturally there is a close relationship between anaerobic threshold (AT) and endurance performance [13, 27, 45, 48]. A correlation was also found between AT and maximal oxygen uptake [30, 52, 55]. However, if the maximal oxygen uptake ($\dot{V}_{O_2}$max) is more closely related to oxygen transport, especially to the cardiac performance [43] then the AT depends, first of all, on the maximal rate of oxidative phosphorylation determined by the mitochondrial enzymes in muscle cells [23, 26, 30, 42, 50] and therefore also by the % of slow twitch fibers [26, 27, 30].

Despite the pronounced individual differences [22, 46] the AT corresponds approximately to the level of arterial blood lactate of 4 $mmol \cdot l^{-1}$ [27, 30, 36]. Kindermann et al. [32] suggested that the lactate level of 4 $mmol \cdot l^{-1}$ would be a good measure of the optimal workload intensity for the improvement of cardiovascular functions. Yoshida et al. [56] showed that the endurance training intensity corresponding to 4 $mmol \cdot l^{-1}$ of arterial blood lactate was effective for the improvement of AT, measured by blood lactate of 4 $mmol \cdot l^{-1}$ ($AT_{4.0}$) as well as of $\dot{V}_{O_2}$ max in healthy male college students. The efficiency of training disappears if the endurance training exercises exceed the $AT_{4.0}$. Thus, the training at the intensity of approximately 4.5 $mmol \cdot l^{-1}$ of blood lactate did not raise the AT. It was achieved when the training intensity was reduced to approximately

3.5 mmol·l^{-1} of blood lactate in female middle-distance runners [18, 19]. The question remains whether the training at $AT_{4.0}$ improves the glycolytic energy production capacity and induces other results of endurance training, too. Among those attention has been paid to the raise of high density lipoproteins concentration [1, 10, 28, 29, 35], inversely related to the risk of coronary heart diseases [20, 37].

The purpose of this study was to compare the effects of two training programs, performed at the intensity of individual $AT_{4.0}$ on the indices of physical working capacity and blood lipids and lipoproteins contents in moderately trained university students. In addition to the determination of $\dot{V}_{O_2}$max and $AT_{4.0}$ the glycolytic energy production capacity was assessed by a 60 sec jumping test, recommended by Bosco et al. [4, 5]. The tested training programs differed in exercise duration.

MATERIALS AND METHODS

The subjects of this investigation were 64 male university students who were divided into two training groups: (1) running training during 20 min in one training session (n = 31), (2) running training during 30 min in one training session (n = 33). Both groups ran in the indoor track on fixed speed corresponding to the individual $AT_{4.0}$ level. They exercised during 8 weeks 3 times per week. Each training session began with a 1.5 km warming-up running in aerobic regime.

To determine $AT_{4.0}$ the running test was performed on the indoor track. Subjects performed three 5 min runs on fixed speeds resting for 1.5–2 min after each exercise for taking blood samples. The speeds were chosen so that the first run was below the level of putative $AT_{4.0}$, the second run approximately on that level and the third run above the level. The running speed corresponding to $AT_{4.0}$ was calculated graphically. The load of a single training session was corrected after 3 and 6 weeks of training. The concentration of blood lactate was determined enzymatically (Boehringer Mannheim, FRG).

The $\dot{V}_{O_2}$max was measured by a bicycle ergometer test. The work load increased by 50 W in every 3 min until the highest possible load was reached. The test terminated by a 1 min sprint at maximal pedalling rate [41]. For measuring the glycolytic power the subjects jumped continuously at the highest possible rate for 60 sec on the force platform (knees about 90 degrees just before the jump and hands kept on the hips throughout). The power output for every 15 sec and for the whole 60 sec exercise was calculated by an equation of Bosco et al. [4].

Before and after the training period blood specimens were obtained by venipuncture in the morning after a 12-hour fast. Glucose, urea and triglyceride (TG) concentrations were measured by LACHEMA (ČSFR) kits. Total cholesterol (CHOL) level was determined by Liberman-Burchard reaction, high density lipoprotein (HDL-C) by heparin-$MnCl_2$ precipitation procedure [7], HDL_3-C was determined by precipitating the HDL supernatant with DEXTRAN SULPHATE (MW 15000) [15]. HDL_2-C was calculated as the difference between HDL-C and HDL_3-C. Low density lipoproteins (LDL-C) were calculated by the Friedewald et al. [14] equation. The load of a single training session was evaluated using Borg's [3] perceived exertion scale.

RESULTS

During the training period the body weight did not change significantly. Various changes were revealed in the values of maximal oxygen uptake (Fig. 1). If the variation of $\dot{V}_{O_2}$ max/kg $\pm$ 3 $ml \cdot min^{-1} \cdot kg^{-1}$ may be considered within the limits of methodological error then an increase in $\dot{V}_{O_2}$ max/kg was recorded in 19 persons from the group of 20-min run and in 16 persons from the group of 30-min run. A decrease in $\dot{V}_{O_2}$ max/kg was recorded in 6 and 4 cases in the groups, respectively. If the initial level of $\dot{V}_{O_2}$ max/kg was below 42.5 $ml \cdot min^{-1} \cdot kg^{-1}$ then in all cases the training was effective in increasing aerobic working capacity. On the other hand, if the initial level was over 62.5 $ml \cdot min^{-1} \cdot kg^{-1}$ then the training was ineffective due to the decrease in the aerobic working capacity. In persons with the initial level within 43 to 62 $ml \cdot min^{-1} \cdot kg^{-1}$ changes in both directions or the lack of significant change was recorded. The comparison of mean values of the groups allowed to establish a significant levels between the groups did not differ.

The changes in both directions were revealed also in running speed corresponding to the anaerobic threshold (Fig. 2). Considering changes of $AT_{4.0} \pm 0.2$ $m.s.^{-1}$ to be within the limits of methodological error, the increase was established in 23 persons and decrease in 15 persons. The distribution of cases of improvement was almost equal between the groups. Most of the cases of improvement were common in persons with the initial level of $AT_{4.0}$ below 3.2 $m.s.^{-1}$. There was not any dependence of the change in $\dot{V}_{O_2}$max/kg on the initial level $AT_{4.0}$ (Fig. 3) or of change in $AT_{4.0}$ on the initial level of $\dot{V}_{O_2}$max/kg (Fig. 4).

The results of Bosco test [4] are presented in Fig. 5. During the training period the power output during 1-min jumping did not increase significantly ($p > 0.05$). Only in the group of 30-min run the power output from 15 to 30-s test was higher after the training

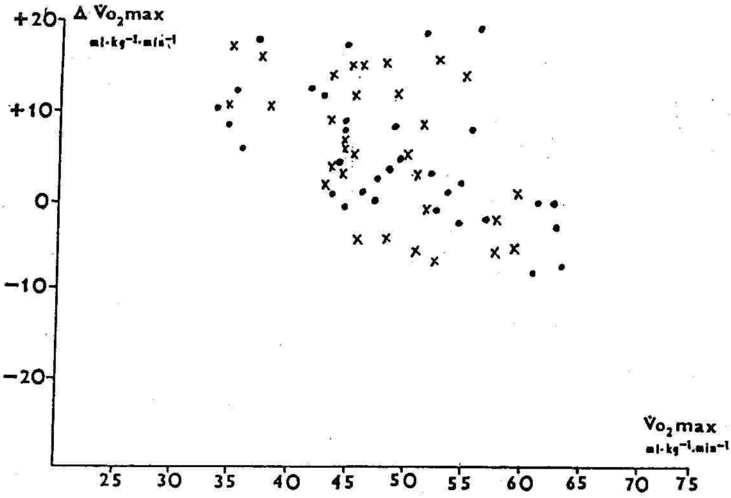

Fig. 1. The relationship between the initial level of $\dot{V}_{O_2}$max and the change in $\dot{V}_{O_2}$max due to 8 weeks training. x — persons of the group of 20 min run, • — persons of the group of 30 min run.

period than before ($p < 0.02$). Statistically significant correlations between aerobic working capacity, $AT_{4.0}$ and the jumping test results were not obtained.

Mean concentration of glucose in blood plasma decreased significantly in the group of 30-min run. However, it was due to higher initial level (Table). Urea concentration increased moderately but the change was statistically insignificant. CHOL concentration diminished insignificantly in the group of 30-min run but increased significantly in the group of 20 min run. HDL-C levels rose by 30.4 % ($p < 0.001$) in the group of 20 min run. In the group of 30-min run the changes (7.7 %) were statistically insignificant ($p > 0.05$). HDL_2 subfraction increased significantly in both groups (in group of 20-min run by 75.0 % and in group of 30-min run by 32.1 %). Concentrations of HDL_3 and LDL-C did not alter significantly during the training period. The HDL-C/CHOL ratio increased significantly only in the group of 20-min run. Statistically significant negative correlations were obtained in the 30-min running group between $\dot{V}_{O_2}$max and CHOL before ($r = -0.453$) and after ($r = -0.469$) the training period.

Using the Borg's scale, it was established that the perceived exertion during a/the training session was almost equal in both groups (Table).

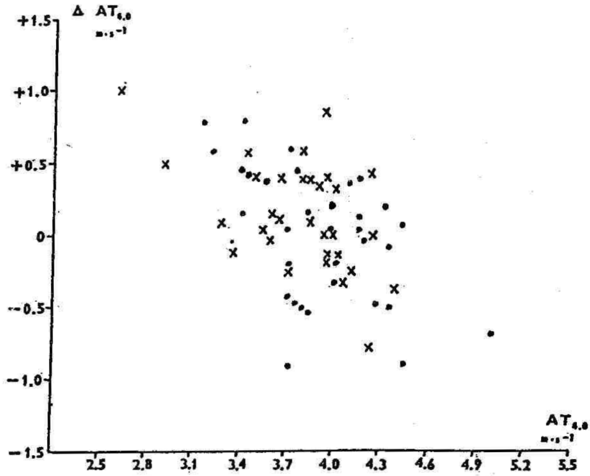

Fig. 2. The relationship between the initial level of $AT_{4.0}$ and the change in $AT_{4.0}$ due to 8 weeks training. x — persons of the group of 20 min run, • — persons of the group of 30 min run.

DISCUSSION

Maximal oxygen consumption is traditionally regarded as a quantitative index of the maximal aerobic performance capacity. In our study the initial mean $\dot{V}_{O_2}$max/kg values of 47 and 49 $ml \cdot min^{-1} \cdot kg^{-1}$ for the 20-min and 30-min running groups, respectively, are similar to those reported for untrained young men [38]. The mean improvement of $\dot{V}_{O_2}$max/kg by 13.1 % in the group of 20 min run is similar to the data reported about training effects in previously untrained males [29, 49]. However, the individual analysis did not prove that the improvement was a common change for most of the persons. The improvement was common only to persons with initial level below 42.5$ml \cdot min^{-1} \cdot kg^{-1}$. Obviously, in applied training regime the stimulus for the development of aerobic working capacity was too small to establish a substantial improvement in each person during 8 weeks of training. The same is true with regard to improvement of $AT_{4.0}$, despite the data demonstrating that AT increase with aerobic training to a greater extent than does $\dot{V}_{O_2}$ [8]. A common improvement of $AT_{4.0}$ occurred only in persons with initial level below 3.2 $m \cdot s^{-1}$.

Was the training stimulus unadequate for some subjects due to

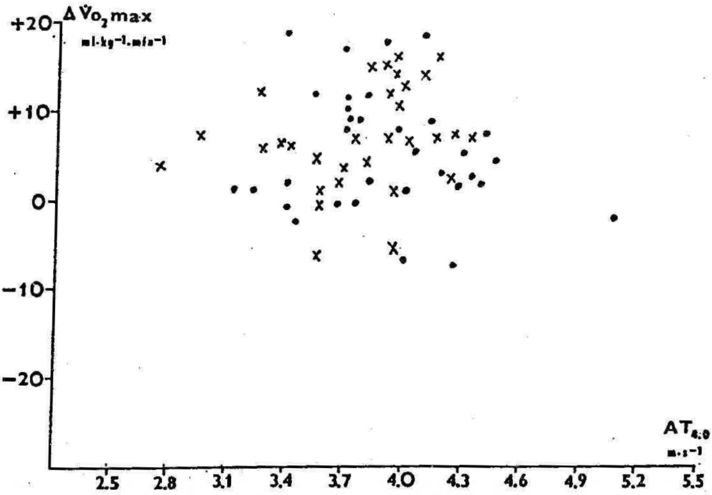

Fig. 3. The relationship between the initial level of $AT_{4.0}$ and the change in $\dot{V}_{O_2}$max due to 8 weeks training. x — persons of the group of 20 min run, • — persons of the group of 30 min run.

too small or too heavy load? In female middle-distance runners it was observed that the training loses its effect in improving AT if the blood lactate level exceeds 4.5 mmol·l^{-1} during training exercises [18, 19]. Hence, one must not exclude the possibility that the unadequate response to training might be due to too intensive exercise. The running speed used by our persons during training exercises was quite close to the data about the speed at the level of $AT_{4.0}$ in untrained male persons [16]. If the intensity of prolonged exercise corresponds to that which resulted in blood lactate level 4.0 mmol·l^{-1} during short-term test exercises then lactate concentration increases during the first 15–20 min to reach a constant value to be maintained up to the end of exercise. However, the obtained level is not exclusivly 4.0 mmol·l^{-1}. In one study the mean value was 5.3 mmol·l^{-1} [32] and in another study of middle-distance runners — 5.5 mmol·l^{-1} [2]. The question remains, did the running speed at 4.0 mmol·l^{-1} really correspond to the anaerobic threshold of our subjects? The answer would make it clear whether the training stimulus was too low or too heavy. However, good responses to training of persons with low initial levels of $\dot{V}_{O_2}$max/kg and $AT_{4.0}$ suggest that for the general contingent of persons the 20 and 30 min exercises at the intensity levels correspond to the lactate of 4.0 mmol·l^{-1} in 5-min running give sufficient stimulus for improvement of both $\dot{V}_{O_2}$max and $AT_{4.0}$.

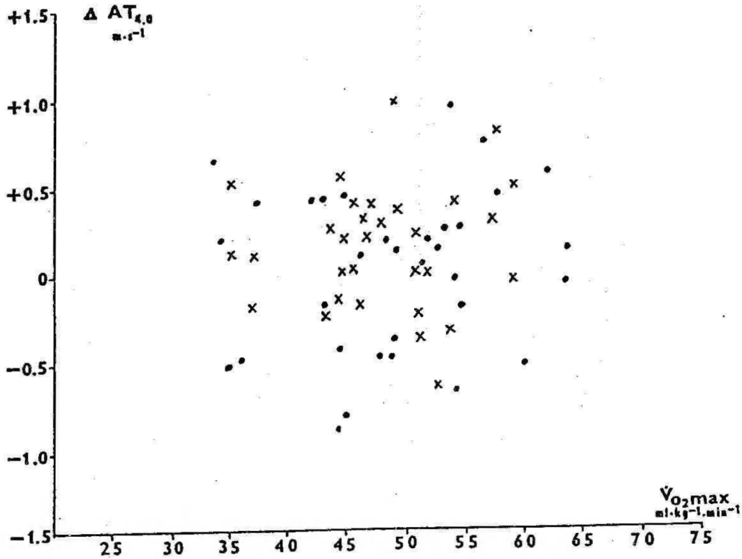

Fig. 4. The relationship between the initial level of $\dot{V}_{O_2}$max and the change in $AT_{4.0}$ due to 8 weeks training. x — persons of the group of 20 min run, • — persons of the group of 30 min run.

In disagreement with the results of some other studies [47] we did not establish a correlative relationship between $\dot{V}_{O_2}$max and AT values. Our results thus confirm the view about a different mechanism limiting the levels of $\dot{V}_{O_2}$max and AT [17, 23, 44].

The power output recorded during the 60 sec jumping test did not change significantly in both training groups. On the one hand, it confirms the well known fact about the specificity of the training effects. On the other hand, it disagrees with the possibility that the intensity of used training exercises exceeded the actual level of anaerobic threshold.

Several reports have proved that a significant rise of HDL-C accompanies the increase of $\dot{V}_{O_2}$max as a consequence of endurance training [25, 31]. In our study the HDL-C concentration in blood increased only in the group of 20 min run. On the other hand, the HDL-C subfraction HDL_2-C increased significantly in both groups indicating more correctly the decrease of risk factors of coronary heart diseases [11]. In the other studies only an increase in HDL_2-C subfractions with aerobic training [11, 53] was also mentioned. The pronounced increase in HDL_2-C concentration was obviously promoted by the relatively low initial values in comparison with the

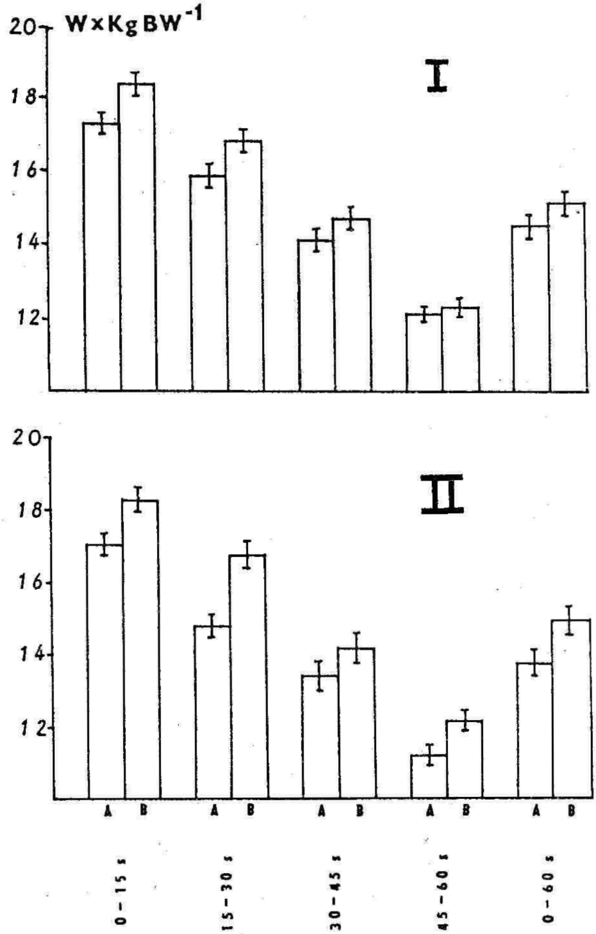

Fig. 5. Changes on the power output during the 60 s jumping test in 20 min (I) and 30 min (II) running groups before (A) and after (B) the training period.

data of the other studies [21].

There are contradictory reports of the effect of exercise training on CHOL in blood: in physically active men the CHOL level is found to be lower than in sedentary men [22, 54], almost the same [33], or even higher [34]. Different results were achieved also in our study: an increase in the group of 20-min run and an unsignificant decrease in the group of 30-min run.

Table

Changes in physical working capacity and blood biochemical parameters during different running training programs (means ± SD)

	20 min running group (n = 31)			30 min running group (n = 33)		
	Before	After	p	Before	After	p
Age (yrs)	19.5 ± 1.2			19.4 ± 1.7		
Height (m)	1.79 ± 0.06			1.81 ± 0.08		
Weight (kg)	74.8 ± 9.0	74.4 ± 8.7	> 0.05	74.0 ± 9.8	73.7 ± 8.9	> 0.05
$\dot{V}_{O_2}$ max ($l \cdot min^{-1}$)	3.526 ± 0.614	3.967 ± 0.608	< 0.01	3.630 ± 0.930	3.916 ± 0.688	> 0.05
$\dot{V}_{O_2}$ max/kg($ml \cdot min^{-1} \cdot kg^{-1}$)	47.2 ± 6.6	53.4 ± 7.1	< 0.01	48.9 ± 9.4	53.0 ± 8.2	> 0.05
$AT_{4.0}$ ($m \cdot s^{-1}$)	3.74 ± 0.38	3.83 ± 0.49	> 0.05	3.89 ± 0.42	3.88 ± 0.42	> 0.05
Glucose ($mmol \cdot l^{-1}$)	5.24 ± 1.26	4.82 ± 0.95	> 0.05	5.80 ± 0.61	4.82 ± 0.84	< 0.001
Urea ($mmol \cdot l^{-1}$)	3.80 ± 1.08	4.28 ± 1.63	> 0.05	4.15 ± 1.55	4.32 ± 1.68	> 0.05
TG ($mmol \cdot l^{-1}$)	1.03 ± 0.50	1.25 ± 0.34	> 0.05	1.48 ± 0.38	1.39 ± 0.31	> 0.05
CHOL ($mmol \cdot l^{-1}$)	4.59 ± 1.03	5.28 ± 1.22	< 0.05	5.25 ± 1.08	5.05 ± 0.76	> 0.05
HDL-C ($mmol \cdot l^{-1}$)	1.15 ± 0.25	1.50 ± 0.33	< 0.001	1.30 ± 0.34	1.40 ± 0.30	> 0.05
HDL_2-C ($mmol \cdot l^{-1}$)	0.24 ± 0.13	0.42 ± 0.19	< 0.001	0.28 ± 0.18	0.37 ± 0.17	< 0.01
HDL_3-C ($mmol \cdot l^{-1}$)	0.91 ± 0.21	1.08 ± 0.28	> 0.05	1.02 ± 0.25	1.03 ± 0.21	> 0.05
LDL-C ($mmol \cdot l^{-1}$)	3.26 ± 0.94	3.56 ± 1.10	> 0.05	3.66 ± 1.02	3.67 ± 0.77	> 0.05
HDL-C/CHOL (%)	25.4 ± 4.9	29.3 ± 7.2	< 0.02	24.8 ± 7.1	27.7 ± 6.7	> 0.05
Borg's test	13.7 ± 2.1			14.2 ± 1.8		

In response to short-term exercise training no changes [24] or a decrease [12] was recorded in serum TG concentration. We did not find any significant change of TG level in response to the running training. All our subjects were normolipidemic (fasting TG below 2.0 mmol·l^{-1}) and therefore a change in TG values could be more difficult to accomplish.

Several studies have found that ratings of perceived exertion at AT are quite constant, corresponding to a Borg scale rating of approximately 13 to 14 [9, 40]. The results of this study are in agreement with this (Table). There were not any significant differences between groups. We must conclude that the training load was "somewhat hard".

To sum up, only the 20 min running three times per week at the level of the individual $AT_{4.0}$ gives sufficient stimulus for improved $\dot{V}_{O_2}$max and $AT_{4.0}$ in young healthy men. However, already at this level of training positive changes were noticed in serum lipoprotein content: an increase of HDL_2-C concentration in both groups and of total HDL-C in the group of 20-min run.

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PHYSIOLOGY OF TRIATHLON
Mini Review

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CONTENTS

1. INTRODUCTION

The triathlon involves open water swimming, cycling and running. This sport event has become one of the most popular endurance events of the 1980's. There are not very constant competition distances, it dependents on the local possibilities. As a rule, original "Ironman" triathlon consists of a 3.8 km swimming, a 180 km bicycle race and a standard marathon run. Very popular are also triathlons in short distances $\frac{1}{2}$ or $\frac{1}{4}$ of the Ironman distance. However, because triathletes complete in three sport events, often over ultraendurance distances, their profiles may differ from that of more conventional athletes. Triathletes need to use the musculature of the upper and lower body and work in the supine and upright position. Most of the physiologic impairings that occur during a triathlete's performance appear during running [71, 97]. With regard to training, the triathlete must carefully plan his training program as the peak aerobic capacity of the arms or legs will generally be limited by the specificity of training [20]. Training loads in the preparatory period before the Ironman competitions are very high, duration of serious training minimally 8 months [52]. Triathletes undergo specific adaptation to training. There are linear relationships among weekly training distances and frequencies in each of the three sport events as well as triathlete's experience [111]. Because of the newness of this sport event, only limited information is available about triathletes. The purpose of this review is to discribe the available information about triathletes and about the physiological adaptation to competition loads.

2. PHYSICAL WORKING CAPACITY OF TRIATHLETES

In triathlon, the total result depends on the sucess in swimming, bicycle and running with musculature of the upper and lower body utilized for the three different events. With regard to physical training, the triathlete must carefully plan his training program as the peak aerobic power of the arms or legs will generally be limited by the specificity of training [20, 49, 55]. It is well known that the maximal oxygen consumption ($\dot{V}_{O_2}$max) is highly dependent upon the mode of testing — the highest values are attained during treadmill running. The $\dot{V}_{O_2}$max is normally 8 to 12 % lower in cycling exercises than in running [15, 54, 60] and 18 to 22 % lower in swimming than in running [3, 32]. In well-trained but not top class triathletes the mean $\dot{V}_{O_2}$max in bicycle was 95.7 % of the treadmill running value and in tethered swimming $\dot{V}_{O_2}$max was 86.6 % of the treadmill running value ($\dot{V}_{O_2}$max/kg was 60.5, 57.9 and 52.5 $ml \cdot min^{-1} \cdot kg^{-1}$ in running, bicycle and swimming). Running and cycling times in the half-triathlon were significantly ($p < 0.01$) related to the corresponding $\dot{V}_{O_2}$max values ($r = -0.68$) and $r = -0.78$ respectively) but swimming times were not [42]. Significant correlations were observed when the peak $\dot{V}_{O_2}$ was correlated with the best performance times during cycling or running in other studies, too [41, 46, 47, 73, 100].

Twelve male amateur triathletes who are comparably trained in swimming, cycling and running exhibit differences in maximal physiological responses to maximal treadmill, bicycle and tethered swimming ($\dot{V}_{O_2}$max/kg was 67.0 ± 3.8, 62.9 ± 3.5 and 59.4 ± 4.1 $ml \cdot min^{-1} \cdot kg^{-1}$ respectively) [58]. Surprisingly Albrecht et al [1] did not note any significant differences between bicycle ergometer and treadmill test in 9 well-trained triathletes. Relatively similar were the mean results in the O'Toole et al. [71] study between treadmill running and cycle ergometer tests. The difference between the treadmill and bicycle test in 10 highly-trained male triathletes was only 5.7 % [57]. We can assume that the differences in $\dot{V}_{O_2}$max between different tests in triathletes depend significantly on the favorite sport event what the athletes trained seriously before specializing in triathlon.

Before the Hawaii Ironman Triathlon $\dot{V}_{O_2}$max/kg in treadmill in males was 72.0 ml·min^{-1}·kg^{-1} and in females 58.7 ml·min^{-1}·kg^{-1} [31]. The $\dot{V}_{O_2}$max/kg in bicycle ergometer of 17 male triathletes was 60.22 ml·min^{-1}·kg^{-1} [82], in ČSFR triathletes 65.9 ± 4.9 ml·min^{-1}·kg^{-1} [63], in Estonian triathletes 59.6 ± 7.8 ml·min^{-1}·kg^{-1} (our unpublished data). Average $\dot{V}_{O_2}$max/kg for the male triathletes is slightly lower than that of elite marathon runners and cyclists. On the other hand their body fat percentage and lean body mass is slightly higher, too. The percentage of body fat in male triathletes mostly varied 5–10 % [31, 71, 99] and in female triatletes 10–20 % [31, 71, 87].

There are only a few data about the submaximal working capacity of triathletes. The economy (% $\dot{V}_{O_2}$max) of effort is of greater importance to a triathletes performance than $\dot{V}_{O_2}$max [11]. In 10 male triathletes the ventilatory threshold occurried at proportional percents of $\dot{V}_{O_2}$max among swimming, cycling and running and here dependent on the athletes $\dot{V}_{O_2}$max in each exercise [45]. In another study the ventilatory and lactate (4.0 mmol·l^{-1}) thresholds of triathletes correlated significantly with bicycle ergometer and treadmill results but not with those of swimming. In swimming the anaerobic threshold was lower than in running or bicycle when expressed in % $\dot{V}_{O_2}$max [1]. According to our unpublished data in moderately trained amateur male triathletes the mean speed by running at 4.0 mmol·l^{-1} of lactate in blood was at the beginning of the preparatory period 4.23 ± 0.26 m·s^{-1} and in swimming 0.97 ± 0.14 m·s^{-1}.

In our opinion we need correct regular anaerobic threshold measurements for two purposes: (1) to correct the training intensity in swimming, cycling and running and (2) to correct the intensity during competition. High $\dot{V}_{O_2}$max alone did not predict success in triathlon. Contrary to that Mayers et al. [53] concluded that running performance which follows cycling is impaired and that $\dot{V}_{O_2}$max and anaerobic threshold data may not be good predictors of triathlon performance.

3. ENERGY METABOLISM DURING THE TRIATHLON COMPETITION

Success in triathlon appears to be influenced by the ability to maintain thermal and mechanical efficiency throughout the event. Thermoregulation appears to be a critical factor in a successful triathlon performance [45]. Triathletes should ingest fluids frequently throughout the competition in an attempt to minimize rise in care temperature, possible fluid shifts [107], dehydration [30] and impaired performance [45,110] reported during a prolonged performance. It is found that a triathlon competition lasting about 10 hrs demands about 6000 kcal of energy [2].

The oxidative breakdown of lipid substrates covers the main part of the energetic demands during the triathlon competition. The free fatty acid concentration increased 2–5 fould after a triathlon competiton [31, 101]. Glycerol concentration increases rapidly too [101]. Intramuscular triglyceride stores have been shown to contribute significantly to energy metabolism [14]. Triglyceride concentration in blood does not change [31, 101] or decreases [36, 91, 105]. Very low lactate concentrations in blood after triathlon competitions also indicates, that work was mostly performed at the aerobic level using fats as an energetic fuel [27, 40, 65]. It is wellknown that high concentrations of lactate in blood inhibit the release of fatty acids from adipose tissue.

There are only a few reports on the influence of triathlon competitions on serum lipo- and apolipoprotein concentrations. According to our data the total CHOL, HDL-C and LDL-C did not change significantly after the short and long triathlon [36]. Total CHOL and HDL-C did not change and LDL-C increased significantly during the long triathlon [74], HDL-C was significantly higher when compared with its initial level 30 hrs after the "Superironman" (5.0 km swimming, 250 km cycling, 50 km running) competition [69]. The CHOL concentration increased 7 %, HDL-C increased 9 % and HDL_2-C increased 11 % in male Japanese triathletes during the Hawaii Ironman competition. In females there were not any significant changes [34]. The Apo-AI and Apo-AII changed little during the long triathlon, Apo-CII decreased significantly and Apo-E increased significantly [61].

Sometimes the depletion of muscle glycogen stores and the development of hypoglycemia can result in exhaustion during prolonged exercise [28, 38]. During triathlon competitions the hypoglycemia does not develop as a rule [6, 31, 36, 89, 101]. Only in one study hypoglycemia was noted after triathlon [30]. Triathletes normally drink carbohydrates in the feeding stations and elevate the glycose levels in blood. Therefore the hypoglycaemia is not a significant limiting factor in triathlon.

Data reported in the literature on the effect of endurance exercise on protein metabolism are conflicting. During relatively short (1.5 hr) and moderate intensity (30 % $\dot{V}_{O_2}$max) exercise the net protein breakdown does not change [108, 109], but more prolonged (3.75 hr) and intensive (50 % $\dot{V}_{O_2}$max) exercise decrease protein synthesis and increase the amino acid catabolism [59]. Latest studies indicate that 3 hr of cycling and 5 hr of treadmill running do not increase net protein catabolism in top-level triathlonists [90]. A significant decrease of several plasma proteins after the Ironman competition is explained by the extraordinary endurance load connected with the excessively negative energetic balance during the competition [64]. The urea concentration in blood increased in most studies [26, 68, 105] but not in all [90], and total proteins did not change significantly [69].

Using an optimal intensity during a triathlon competition and an optimal eating and drinking regime will cause no energetical defficiencies in triathletes.

4. SERUM ENZYMES DURING TRIATHLON RACE

The serum creatine kinase (CK), lactate dehydrogenese (LDH) and transaminase activities increased significantly as a rule, after a triathlon competition [16, 22, 31, 50, 69, 75, 95, 101]. There is a statistically significant relationship between conditioning and duration of race on CPK and LDH with a slightly greater influence seen by duration [82]. Changes in plasma enzymes are altered by training. The rise in serum CK reflects tissue damage. Mechanical trauma has been suggested because the exercise induced changes dependent on the type of exercise performed [29]. After 8–9 hr of running the CK and LDH are higher than after of a triathlon competition of the same duration [16, 22]. Running might have induced considerable muscle disorders whereas swimming does not impose sufficient trauma to produce a release of the intracellular contents [93]. Skeletal muscle injuries are dependent on such factors as exercise intensity, duration and level of physical fitness [24, 80]. Individuals with a lower $\dot{V}_{O_2}$max show a greater rise in serum enzymes than those with a higher $\dot{V}_{O_2}$max [84]. On the other hand, in trained subjects serum enzymes increase more than in untrained ones as a rule [5].This can be explained by the fact that for more fit the quantity and intensity of the work is greater than for untrained persons. The novice endurance athletes might reach peak plasma enzyme levels immediately after the race, whereas much higher enzyme values might be reached by experianced athletes only 24 hr after the race. Novice athletes either develop more severe glycogen depletion than do experianced athletes or, alternatively, they become glycogen depleted earlier in the race and must, therefore, run for a longer period in this depleted state [62].

After 5 to 6 days following the Ironman competition all enzymes remained elevated above the initial values in all competitors [31]. Contrary to that Novak et al. [66] show that on day 5 after the "Superironman" there was a normalization in the activity of CK in all the sportsmen. The LDH decreased significantly 24 hr after a short triathlon [89].

In sum, most enzymes measurements yielded no new data about triathlon competition compared with previous studies in other endurance events.

5. HORMONES DURING TRIATHLON COMPETITION

It is well known that the sympathoadrenal system plays a major role in controlling the supply of energy substrates to the working muscles [18]. During long distance run the increased lipolysis is to be related to the higher concentration of blood epinephrine and norepinephrine [19, 39]. Lipolysis in the adipose tissue is much more sensitive to the norepinephrine released locally from sympathetic nerve endings than to the circulating catecholamines [79]. On the other hand, the lack of epinephrine release allows a slow glycogen breakdown [76]. Surprisingly, during the 10 hr triathlon race the epinephrine and norepinephrine concentrations do not change significantly [16]. These results are very difficult to explain.

During triathlon competition, mostly in swimming, the effects of thermoregulation and water immersion considering hormonal and circulatory adaptations. Thermogenesis can be induced mostly by norepinephrine and to a smaller degree by epinephrine [35]. Already in resting position at 6°C on land induced a strong increase in norepinephrine and small in epinephrine. Work during 45 min at an anaerobic threshold level on the bicycle ergometer at the same temperature did not increase the norepinephrine level above the range that was reached during cold strain at this temperature. The epinephrine values were only slightly higher. Similar work at 26°C increased especially the norepinephrine level (2–3.52 times higher than during the work at 6°C [106]. We can conclude that cold and hot whether or water immersion what are typical to triathlon competition increased mostly the norepinephrine concentration by increasing the lipolysis in the adipose tissue. On the other hand by using wet suits during swimming to prevent hypothermia, the triathletes might swim approximately 5 % faster [96].

The blood cortisol concentration reaches a very high level during competiton in triathlon [36, 77, 86, 98, 100]. The high cortisol increase during a triathlon competition is dependent on swimming in cold water, the highest circulation levels being found during exercise in a cold environment [13, 104]. There is a negative correlation between the rectal temperature and the change in blood cortisol concentration [13]. On the other hand, an increase in body temperature may promote the exercise-induced increase in cortisol concentration [17]. During prolonged exercises the dynamics of activity of pituitary-adrenocortical system is characterized by a preliminary rise, subnormal level (mainly during the second hour of exercise) and a secondary and stable increase in activity [103]. The increased level of cortisol in blood is commonly observed after a very prolonged exercise [103], obviously reflecting the secondary increase in pituitary-adrenocortical activity. In our study it was accompanied by an increased level of progesterone in blood [36]. In a male organism the progesterone is formed as an intermediate link in the biosynthesis of other steroid hormones. As the dynamics of progesterone coinsides with the dynamics of adrenocortical hormones but not with that of testosterone we may connect the increased level of progesterone with the high intensity of steroid biosynthesis in adenals. Hence, the secondary stable increase in a adrenocortical activity is based on the high level of hormone biosynthesis. The changes in cortisol are in a good correlation with the changes in β-endorphin concentration after a trilathlon competition [85].

In our study the testosterone concentration in blood increased moderately after the short triathlon and significantly decreased after the long triathlon [36]. Similar results are presented in other studies, too [86, 98]. Testosterone shows a biphasic behaviour during physical exercise. After an initial increase, the testosterone levels decrease after an exercise which duration exceeds 3 hr [23]. The behaviour of the testosterone sex hormone binding globulin ratio during the 4-day recovery suggests that intense prolonged exercise leads to an anabolic deficit for several days [86]. After a prolonged exercise as a rule, the concentration of testosterone in females increased [12]. It suggests (1) an increase in adrenal steroid production, (2) an impairment in androgen aromatization at the ovarian and peripheral levels.

During triathlon competition the concentration of somatotropin decreased [83] or increased [36]. After a prolonged exercise with rising body temperature somatotropin concentration normally increased [39, 104]. In low temperature this effect is not observed [13, 19]. Taking into account the role of somatotropine in the mobilization of lipid resources we can positively evaluate the rise in somatotropine levels during a prolonged exercise. The mobilization of lipid resources is presented by the decrease of insulin level [36]. The latter is a typical response to a prolonged exercise. The parallel decrease of insulin and C-peptide concentration in blood points to the decreased secretion by pankreas [18, 103].

The rise of blood aldosterone level is a common response to a prolonged exercise and reflects the homeostatic activity in maintaining the electrolyte balance [103]. The increase in aldosterone concentration is secondary to an increase in adrenal secretion and to a decrease in aldosterone catabolism. Metabolism of aldosterone in the liver is directly correlated with the hepatic blood flow, which is reduced by muscular exercise [81].

Exercise induced lipolysis is augmented in hyperthyroid and reduced in hypothyroid states, probably because thyroid hormones potentiate the stimulation of lipolysis by catecholamines [17]. Unfortunately there are no data about the adaptation of thyroid hormones to the triathlon competition.

We can conclude that in well-trained triathletes the hormonale mobilization for increasing lipid metabolism during competition is optimal. As a rule, there is no hard exhaustion syndrome. There are no data about the hormonal adaptations in females.

6. PLASMA ELECTROLYTES DURING TRIATHLON COMPETITION

In long term endurance events the performance can be limited by fluid and electrolyte loss in the form of sweat [6, 7]. The extreme dehydration leads to a decreased work capacity [70] and may be a contributing factor in the development of hyperthermia [21].

Data from short and long triathlon suggest that nearly all triathletes break down red blood cells during a race and that the extent of the hemolysis is related to the race distance [72]. During long triathlon competition potassium and sodium concentration do not change significantly [69] or there may be an increased sodium and a decreased potassium concentration [101] or an increased potassium concentration [67]. Long duration exercise increase mostly potassium concentration [4, 9]. The increase might be provoked by the intracellular space having lost potassium because of an insufficient activity of the Na/K pump in relation to potassium efflux. On the other hand, the decrease of potassium after the exercise might result from an increased loss of potassium by sweat and kidney. The changes are dependent on the different concentrations of sweat, too.

During triathlon competition the calcium concentration increases and the magnesium concentration does not change [101], or magnesium and calcium increase [48] or magnesium concentration does not change [26] or decreases [50]. The magnesium concentration decreased during prolonged exercise [78] as a result of an exchange of magnesium between the plasma and other body compartments, including muscle [8] and erythrocytes [92].

Serum iron concentration decreased during triathlon competition [101]. It may be explaned by the iron loss through sweating [102]. On the other hand, prolonged exercise rises serum iron concentration [25, 43]. Increase in iron concentration can be explaned by release of myoglobin into the blood stream occuring after a skeletal muscle damage, by a release of iron from stores and a release of hemoglobin from red blood cells, hemolyzed during excretion.

The influence of triathlon competition to the electrolyte balance is not completely studied. There are many contradictory data which need future investigations.

7. CHANGES IN PLASMA VOLUME DURING TRIATHLON COMPETITION

Endurance exercise results in an approximately 10 % plasma volume reduction [10, 51]. Many factors effect plasma volume — such as preexercise water intake, changes in posture, blood sampling technique and onset of exercise [33, 37]. Body weight losses during competition were indicative of dehydration. Weight losses incurring during the triathlon normally exceed the values reported for other endurance events. There may be three explanations: (1) an underestimation of the rate of sweating as a major causal factor in the excessive weight losses observed, (2) negligence on the part of endurance athletes to ingest enough fluids, especially during the early stages of an event, and (3) the environmental conditions, such as high-risk temperatures to contract heat illnesses [101]. The plasma volume normally decreased more than 10 % during triathlon competition [56, 61]. The changes in plasma volume during the three different events are contradictory. According to one study the plasma volume decrease 3.8 ± 1.3 %, 4.3 ± 2.1 % and 6.2 ± 1.7 % (total 14.3 %) during swimming, bicycle and running [56]. In the long triathlon the highest plasma loss was during swimming (12.4 %), the changes during biking and running were 6.9 % and 4.4 %, against the rest of the value [61]. The high decrease in the plasma volume during swimming is explaned not only by the load of the exercise but by other factors such as the cooling effects by sea temperature and the unconsious drinking of hypertonic sea saline. On the other hand, plasma volume is greater in the supine than in the upright position [88, 94].

We can conclude that there are relatively high changes in plasma volume during the triathlon competition and the changes in other biochemical parameters can significantly dependent on the changes in plasma volumes.

8. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The triathlon competition, especially its long variant, the so-called "Ironman competition", is one of the longest competitions in the sport practice. The triathletes have a high $\dot{V}_{O_2}$max value, surprisingly, their submaximal working capacity is relatively poorly studied. It is well known that one of the aims of triathlon training is to increase the anaerobic threshold. The high anaerobic threshold level guarantees a relatively high speed during the competition in swimming, bicycling and running. Establishing optimal training intensity based on the % $\dot{V}_{O_2}$max or heart rate is also dependent on the specific mode.The sucess in triathlon depends on the economy component of an exercise. A poorly studied technique is hard to change.

From the physiological point of view the most dangerous component during a long triathlon are hypoglycaemia, changes in the fluid-electrolyte balance, extreme changes in thermoregulation. More experiments are needed to study the recovery periods — normalization of the biochemical parameters. We do not know the influence of the Ironman competition on females. Future research is also needed for the optimal clothing during the competition, especially important is the question of using special wet suits during swimming.

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PHYSICAL WORKING CAPACITY OF TRIATHLETES

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INTRODUCTION

In triathlon, the total result depends on the success in swimming, bicycle race and running, with the musculature of the upper and lower body utilized for the three different events. With regard to physical training, the triathlete must carefully plan his training program as the peak aerobic power of the arms or legs will generally be limited by specifics of training [3, 7]. It is well known that the maximal oxygen consumption ($\dot{V}_{O_2}$max) is highly dependent upon the mode of testing. In welltrained but not top level triathletes the mean $\dot{V}_{O_2}$max in bicycle was 95.7 % of the treadmill running value and in tethered swimming $\dot{V}_{O_2}$max was 86.6 % of the treadmill running value [6]. Surprisingly Albrecht et al. [1] did not note significant differences between bicycle ergometer and treadmill test in 9 welltrained triathletes. There is no information about the anaerobic working capacity of triathletes.

The aim of the present investigation was to compare aerobic and anaerobic functional capacity in top level junior and senior ČSFR triathletes.

METHODS

Seven junior (17.4 ± 1.1 yrs, 176.4 ± 4.2 cm, 65.7 ± 5.2 kg, body fat % 7.7 ± 1.8) and six senior (21.2 ± 1.5 yrs, 178.6 ± 5.9 cm, 70.2 ± 5.7 kg, body fat % 6.3 ± 1.0) highly trained ČSFR triathletes were studied. Their body fat % was measured by the skinfold thickness method [10]. All laboratory tests were conducted within one day. In the morning the $\dot{V}_{O_2}$max was measured by using the treadmill running test (Jaeger, Germany). At first the subjects had 2 submaximal runs for 4 minutes at 0 % 11 and

12 km·h^{-1}. After a few minute rest in juniors running speed in treadmill beginning from 13 and in seniors from 14 km·h^{-1} at 5 % slope by increasing 1 km·h^{-1} every minute until exhaustion. Respiratory parameters were continuously measured by using the Ergooxyscreen (Jaeger, Germany) system. $\dot{V}_{O_2}$max was the mean of the two highest consecutive values of $\dot{V}_{O_2}$. Heart rate (HR) was monitored by Sporttester PE 3000 (Polar Electro, Finland). Blood sample was taken from the earlobe in the 5th minute of recovery and the lactate concentration was measured enzymatically (Boehringer Mannheim, Germany). In the afternoon (after several hours rest) the anaerobic test was used. After a few minute warming-up run, at a 7 % slope the speed 19 km·h^{-1} (juniors) or 20 km·h^{-1} (seniors) was kept constant. The athletes ran until they were no longer able to maintain the treadmill speed. The lactate concentration in blood was measured at the 5th minute of recovery.

Standard statistical methods were used for the calculation of means ($\bar{x}$). Standard deviation (SD) and bivariate correlation analysis (r) were also used. Differences between the mean values were tested for significance using non-paired t-test. The probability level accepted for statistical significance was $p < 0.05$.

RESULTS

The mean results of the aerobic and anaerobic working capacity of the two groups of triathletes are presented in Table. There were not any statistically significant differences between junior and senior triathletes in aerobic or in anaerobic working capacity. HR in the anaerobic test was somewhat lower than in aerobic test: 96.3 % and 98.3 %, respectively, in juniors and seniors. On the other hand, the lactate concentration was higher after anaerobic test: 124.4 % and 119.3 %, respectively, in juniors and seniors. The correlation between lactate concentration after aerobic and anaerobic tests was nonsignificant. Lactate concentration after anaerobic test correlated significantly with the time of anaerobic test ($r = 0.704$) and work output ($r = 0.718$) when calculated for all the subjects ($n = 13$). There were not any significant correlations between the results of anaerobic test on $\dot{V}_{O_2}$max, on body weight or amount of lean body mass.

DISCUSSION

In our triathletes (both juniors and seniors) the $\dot{V}_{O_2}$max/kg was relatively high. These results are in accordance with other studies of highly qualified triathletes [2, 4, 8, 9]. Normally the average

Table

Physical working capacity parameters of triathletes (Means ± SD)

	Juniors (n = 7)	Seniors (n = 6)	p
$\dot{V}_{O_2}$max TEST			
$\dot{V}_{O_2}$max ($l \cdot min^{-1}$)	136.5 ± 12.9	137.0 ± 17.2	ns
$\dot{V}_{O_2}$max ($l \cdot min^{-1}$)	4.79 ± 0.43	4.71 ± 0.20	ns
$\dot{V}_{O_2}$max/kg ($ml \cdot min^{-1} \cdot kg^{-1}$)	73.0 ± 4.3	67.4 ± 4.2	ns
HR_{max} ($beats \cdot min^{-1}$)	197.1 ± 8.1	193.7 ± 5.9	ns
LA ($mmol \cdot l^{-1}$)	10.9 ± 1.7	11.9 ± 2.5	ns
ANAEROBIC TEST			
Time (s)	81.0 ± 18.7	86.5 ± 9.5	ns
Work output ($J \cdot kg^{-1}$)	2094.4 ± 482.4	2346.5 ± 257.3	ns
HR_{max} ($beats \cdot min^{-1}$)	189.9 ± 6.2	190.5 ± 7.1	ns
LA ($mmol \cdot l^{-1}$)	13.6 ± 1.3	14.2 ± 1.3	ns

$\dot{V}_{O_2}$max/kg in triathletes is slightly lower than that of top level marathon runners and cyclists. On the other hand their percentage of body fat and lean body mass is slightly higher, too. Mostly the aerobic working capacity of triathletes is measured separately during swimming, bicycling and running. Total results in triathlon are highly dependent on the success in running [2] and running efficiency is dependent on the high level of $\dot{V}_{O_2}$max [6]. Therefore it is suitable to use treadmill protocols for testing of triathletes.

Endurance-trained subjects are generally known to have an enhanced oxidative and a decreased glycolytic muscle metabolism which could generate such a negative correlation [5]. In case of our triathletes the running time was somewhat shorter during the anaerobic test but the lactate concentration in blood relatively similar to that of middle-distance runners [11]. The correlation between aerobic and anaerobic working capacity in our study was nonsignificant. We must assume that triathletes need for success quite specific high aerobic and anaerobic working capacity. No significant differences between junior and senior triathletes were observed in aerobic or anaerobic working capacity.

We must conclude that in highly trained triathletes have both a high aerobic and anaerobic working capacity. There are no significant differences between juniors and seniors in physical working capacity. We must assume that the differences in their competitive performances are due to other factors than functional predispositions.

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HISTORICAL PROBLEMS OF ATHLETE'S HEART AND ECHOCARDIOGRAPHIC ANALYSIS OF YOUNG AND WOMEN MIDDLE DISTANCE RUNNERS

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INTRODUCTION

At the end of last century the professor of internal diseases from Uppsala University S. Henschen [5] was the first to discover enlarged hearts in cross-country skiers.His statement that "the biggest hearts will win the race" has become popular and well known in sports medicine. S. Henschen got his results by very simple techniques of physical investigation. Heart size was measured by percussion.

His basic findings were as follows:

1. skiing results in the enlargement of the heart,
2. the enlarged heart is able to perform an enlarged work load,
3. an athlete's heart is physiologically enlarged by sports.

He also observed that all parts of the heart are included in this increase. It may be useful to stress the fact that the results of this very important study were achieved by very simple techniques.

It is very interesting to remark that it has always been and still is under discussion whether an athlete's heart is a physiologically highly efficient and healthy heart or a diseased one, or close to the pathologic borderline.

One has to ask the question whether physiological hypertrophy can lead to a pathologic form.

All these problems can be well understood. The experimentator observes a cardiac enlargement during animal experiments as a sign of overloading. The medical doctor deals with hearts of increased size in the case of heart failure and cardiac enlargement in medical practice is an important diagnostic sign. It has a very serious prognosis for the patients' future — great mortality and morbidity in many epidemiologic prospective works [7].

But in sports medicine this topic has basically been substantiated by the assumption of Henschen that "an enlarged heart is something good, if it is able to perform an enlarged load over a long period", — the assessment of athlete's heart as a physiological phenomenon.

Conversely Ewing [3] underlined the economic type of work in trained hearts: a reduction of heart rate, increased stroke volume, decreased myocardial oxygen demand for the same work load.

ANATOMICAL DATA

In the 1930s Kirch [8, 9] published two papers about an investigation of athletes who died suddenly. But low findings were made in the 1930s and not today. There is a tremendous difference between the intensity of athletes training in the 1930s and today. He collected case reports on athletes who died suddenly during or independent of physical activity. The type of sports varied as well as the intensity of training. Kirch observed hearts double in size as compared to normal. In his opinion these hearts were healthy and also capable of an involution of hypertrophy after cessation of training.

An interesting point in the results of Kirch is the unilateral preponderance of hypertrophy of the right side. It was not possible to explain it by the different types of sports.

Next Linzbach [11] tried to give a comprehensive picture of hypertrophy — physiological as well as pathological forms. According to Linzbach the harmonic hypertrophy emphasizes that the structure of the physiologically hypertrophied muscle corresponds exactly to the normal one. The pathological form is characterized by a structural dilation — this is a precondition for myocardical failure.

According to Linzbach structural modifications will occur if the 500 g — limit for a critical heart weight is exceeded.

Histochemical findings showed that the enzymatic pattern of a trained myocardium is only quantitatively but not qualitatively different from the untrained one. During physiological hypertrophy the number of myocardial fibers remains constant. According to him the capillary/fiber relationship will be maintained in the case of pathological hypertrophy. This includes the possibility of hyperplasia.

Other researchers have not agreed with Linzbach's opinion.

Another point that is problematic for other researchers is the critical heart weight. Their consideration is following — Kirch's data were found in moderately trained athletes. According to recent investigations, the cardiac volume of such athletes will not exceed 1200 ml. Therefore the hearts with a higher volume — for example 1700 ml should have a higher weight. A new hypothesis arose that "the critical heart weight" is determined by the individual body size.

On the other hand the conception of "critical heart weight" will be useful indicating that the physiological hypertrophy does not occur unrestrictively.

Radiological data found by Reindell [18] already in the 1950s and the hearts of today's athletes, showed no increase of the heart volume despite the increasing training intensity and volume and the phantastic improvement in the scores in endurance sports. From this arises the idea that the myocardial hypertrophy seems to have been the idea that the myocardial hypertrophy seems to have been reached very early and all the following improvements are thus metabolic and peripheral vascular adaptations.

HEART DIMENSIONS

It is the irony of fate that S. Henschen's work made by percussion was published in 1899 but in 1895 W.K. Röntgen published his investigation on x-rays. And in 1902 Moritz [15] published the first radiological study on the increased hearts in athletes. In 1934 Moritz [16] used quantitative planimetric evaluation of the heart.

Roher [19] and independently Kahlstorf [6] introduced cardiac volume measurements. In Germany the cardiac volume evaluation was performed according to Musshof's modification.

In the 1950s this work was continued by Reindell [18]. According to him the heart can be considered healthy when the relation between the cardiac size and the maximum oxygen uptake per heart beat is within the normal range.

A.G.Dembo [25] discovered that the heart volume depends greatly on the body dimensions of the athletes. Therefore, alongside with the absolute values of the heart volume, it is very useful to take into account the relative values of the heart volume. This way we can eliminate the great differences in height and in body mass of the athletes.

Maybe the best way to eliminate these differences is to use indexes to the body surface area. The formula of the body surface area according to De Bois includes values of height and weight. Some researches use all of them simultaneously to eliminate the body dimensions influence better.

But the famous Soviet scientist A.G. Dembo [25] has emphasized that it is difficult to make use of this method because specially equipped x-ray rooms and a large amount of photo (roentgenograms) are needed. Therefore in Dembo's opinion the study by T. Karu [27], A. Landõr and T. Karu [28] on the use of the fluorographic method for the same purpose is of great importance. Over twenty years this method has been used in the department of sports medicine of Tartu University by T. Karu, J. Maaroos, A. Landõr and M. Ojamaa, in Tartu Sports Medicine Center and in the Faculty of Physical Education by sportsphysiologist J. Jürgenstein [31], A. Pisuke [17] and so on. The results of A. Landõr's [28] prolonged study showed that this method gives similar results as the study of Reindell [18].

The endurance trained athletes (cross-country skiers, cyclists, basketball players) had the greatest heart volumes and sprinters, gymnasts, heavy athletes had smaller hearts. But all the sportsmen groups had greater hearts than the nonsportsmen group.

The male athletes had a larger heart than female. Maybe this shows that physiological hypertrophy is less pronounced in women.

ECHOCARDIOGRAPHY

In this field the Swedish scientist Edler and Hertz [2] were the first to use the ultrasound to diagnose mitral valve stenosis, the intraventricular septum thickness and the left ventricular posterior wall thickness measurement. V. Zaretski's [26] and N. Mucharljamov's studies [29, 30] were the first in this field of research in the Soviet Union.

By echocardiographic method we can distinguish the diameters of the chambers of the heart and at the same time determine the diameters of the intraventricular septum between the right and left ventricle and the left ventricular posterior wall diameter.

In the field of sports medicine the first important echocardiographic investigation was that of Rost in Olympic athletes in Munich [20].

In 1975 J. Morganroth et al. [14] were the first to point out that cardiac adaptation to the isometric work of heavy athletes is rather different from that of athletes trained to isotonic exercises (endurance exercises). In the heart of athletes trained by isometric exercises he found "a pure concentric hypertrophy" — that is the increased thickness of the intraventricular septum and posterior wall of the left ventricle, but no increase of the enddiastolic diameter.

In contrast he found "a pure dilatation" or excentric hypertrophy in endurance athlete's heart — that is no increase of the thickness of intraventricular septum and posterior wall of the left ventricle, but a clearly increased left ventricular enddiastolic diameter.

This echocardiographic pattern of the structure of the heart had a hemodynamic explanation. During isotonic work or running the systolic value of arterial pressure increases slightly, the diastolic arterial pressure remains unchanged or slightly decreased, the cardiac output and stroke volume of the heart increase.

The hemodynamic pattern is different during isometric work: the systolic as well as diastolic arterial pressures increase, the heart has to work against elevated blood pressure. That is why the work load and hypertrophy of the myocardium increase.

We can also say that the dominant "volume type of work" of the heart is typical of endurance athletes. But the predominant "pressure type of work" is characteristic of the heart working during isometric performance.

All in all the myocardial thickness of the left ventricle of athletes has only been 1–2 mm (in some cases more) bigger than in normal control groups.

Some investigators have pointed out that an asymmetric septal hypertrophy — a septal/free wall ratio exceeding 1.3 can be found in healthy athletes [12, 21].

The experience of Rost has shown that an increased ratio has to be related to fairly thin backwall of the left ventricle [21].

In athletes the left ventricular enddiastolic diameter is slightly increased, the dimensions are frequently limited to normal but in extreme cases and in tall sportsmen they exceed normal ones.

Some problems concerning the athlete's heart have not been completely solved:

— a genetic predisposition to the development of athlete's heart, e.g. which heart is able to increase to 1700 ml [10];

— at which age physiological hypertrophy takes place: before puberty, during adolescence, past the age of 20 or it can happen even at the age of 40 [12, 21];

— problems of the reversal of heart hypertrophy after the cessation of training [23];

—problems concerning the risk of sudden death of athletes [4, 13];

— problems of cardiac enlargement as a future risk factor [12, 21].

Different authors give quite different answers to these problems. Most of the studies of the athlete's heart have been directed toward males while little attention has been paid to female athletes [12].

The purpose of our study was to compare the left-sided cardiac dimensions in the three groups of female middle distance runners — young beginners, good young runners and student middle-distance runners.

The problems we wished to get answer to were the following:

— are there any different echocardiographic dimensions between beginners and good middle distance runners of the same age?

— is there any difference between the echocardiographic dimensions of good young runners and student middle distance runners?

METHODS AND MATERIAL

The study group consisted of 49 female middle distance runners. They were divided into three groups:

Group I consisted of 22 beginners aged 14.7 ± 3.4 years, with the height of 162.5 ± 8.3 cm and with the bodymass of 48.8 ± 9.0 kg.

Group II consisted of 17 good young runners aged 15.1 ± 0.6, with the height of 165.7 ± 5.3 cm and with the bodymass of 52.3 ± 6.4 kg.

Group III consisted of 18 student runners aged 19.7 ± 1.3 years, with the height of 171.1 ± 4.7 and with the bodymass of 62.1 ± 6.1 kg.

All the groups were normotensive, free from known cardiovascular diseases and had the normal sinus rhythm during the study.

All the subjects had technically adequate M–mode and 2 dimensional echocardiograms performed by the same observer using a 3.5 MHz transducer and standard acquisition techniques. We used the echocardiogrpah ATL Mark 5 Advanced Technology Labs.

M–mode measurements were made according to the leading edge, following the recommendations of the American Society of Echocardiography [22] and averaging 3 cardiac cycles. The following echocardiographic parameters were obtained: enddiastolic left ventricular diameter (LVEDD) measured at the onset of the QRS–complex and endsystolic left ventricular diameter (LVESD) at minimal cavity dimension, enddiastolic left ventricular posterior wall (PW) and interventricular septum wall thickness (IVS). The left ventricular ejection fraction (EF) was calculated by the single-plane area–length volume formula, referred to as the Teichholz et al. method [24]. The stroke volume (SV) was also calculated by the Teichholz et al. method [24]. The left ventricular mass (LVM) was calculated by the M–mode echocardiogramm using modified formula of Devereux et al. [1]. The aortic root diameter was measured at the end of diastole. The left atrial diameter (LAD) was measured in systole from the leading edge of the posterior aortic wall to the leading edge of the posterior left atrial wall.

RESULTS AND COMMENTS

Our data are given in Tables 1, 2, 3, 4. The data are expressed as mean ± standard error of the mean. The results were analyzed using the unpaired Student t–test. The statistical significance was considered at $p < 0.05$.

In the present study we found that the beginners and good young middle-distance runners had no differences in the left ventricular

Table 1

Demographic Data

	Good young runners n = 17	Beginners n = 22	p–value
Age (years)	15.1 ± 0.6	14.7 ± 3.4	NS
Height (cm)	165.7 ± 5.3	162.5 ± 8.3	NS
Weight (kg)	52.3 ± 6.4	48.8 ± 9.0	NS
Body surface area (m^2)	1.569 ± 0.1	1.500 ± 0.2	NS

NS — difference not significant

Table 2

Echocardiographic Data

	Good young runners n = 17	Beginners n = 18	p–value
Aorta size in diastole (mm)	25.1 ± 0.21	24.0 ± 0.3	< 0.05
LA size (mm)	31.4 ± 0.5	30.0 ± 0.5	NS
LV size in diastole (mm)	44.3 ± 1.1	42.0 ± 1.5	NS
LV size in systole (mm)	24.4 ± 0.8	22.8 ± 1.9	NS
Septal thickness (mm)	8.2 ± 0.6	8.1 ± 0.9	NS
LV posterior wall thickness (mm)	8.3 ± 0.4	8.3 ± 0.5	NS
Stroke volume (ml)	68.4 ± 11.8	60.2 ± 11.8	< 0.05
Ejection fraction (%)	76 ± 5	76 ± 9	NS
LV mass by M-mode (g)	93 ± 2.0	86 ± 20	NS
Aorta size index (mm/m^2)	16 ± 1.0	16.2 ± 2.1	NS
LA size index (mm/m^2)	20 ± 1.4	20.2 ± 3.0	NS
LV size in diastole index (mm/m^2)	28.3 ± 2.3	28.0 ± 1.5	NS
LV size in systole index (mm/m^2)	14.9 ± 2.3	15.2 ± 1.9	NS
Septal thickness index (mm/m^2)	5.3 ± 0.4	5.6 ± 0.6	NS
LV posterior wall thickness index (mm/m^2)	5.3 ± 0.4	5.6 ± 0.6	NS
Stroke volume index (ml/m^2)	44 ± 7	40 ± 7	NS
Ejection fraction index (%/m^2)	49 ± 5.2	51 ± 8.2	NS
LV mass by M–mode index (g/m^2)	59 ± 11	57 ± 11	NS

LA — left atrium
LV — left ventricular
NS — difference not significant

dimensions and in the left ventricular wall thickness.

Only the aortic root dimensions and the stroke volume of good young runners were greater than those of beginners of the same age,

Table 3

Demographic Data

	Student runners n = 18	Good young runners n = 17	p–value
Age (years)	19.7 ± 1.3	15.1 ± 0.6	< 0.001
Height (cm)	171.1 ± 4.7	165.7 ± 5.3	< 0.01
Weight (kg)	62.1 ± 6.1	52.3 ± 6.4	< 0.001
Body surface area (m^2)	1.725 ± 0.1	1.569 ± 0.1	< 0.001

height and weight.

This observation can be explained by the right selection on the one hand, on the other hand, probably by the low training load of the good young middle–distance runners which has not yet caused the adaptive cardiac dilation.

Table 4

Echocardiographic Data

	Student runners n = 18	Good young runners n = 17	p–value
Aorta size in diastole (mm)	24.7 ± 1.1	25.1 ± 0.21	NS
LA size (mm)	27.7 ± 2.8	31.4 ± 0.54	< 0.001
LV size in diastole (mm)	44.7 ± 3.5	44.3 ± 1.1	NS
LV size in systole (mm)	25.6 ± 3.3	24.4 ± 0.8	NS
Septal thickness (mm)	8.7 ± 1.1	8.2 ± 0.6	NS
LV posterior wall thickness (mm)	9.1 ± 0.9	8.3 ± 0.4	< 0.001
LV ejection fraction (%)	74 ± 7.5	76 ± 5.0	NS
Stroke volume (ml)	70 ± 13	68 ± 12	NS
LV mass by M–mode (g)	141 ± 27	93 ± 21	< 0.001
Aorta size index (mm/m^2)	14.4 ± 1.0	16.0 ± 1.0	< 0.001
LA size index (mm/m^2)	16.1 ± 1.5	20.0 ± 1.4	< 0.01
LV size in diastole index (mm/m^2)	26.3 ± 1.9	28.3 ± 2.3	< 0.001
LV size in systole index (mm/m^2)	14.9 ± 2.3	15.6 ± 1.5	NS
Septal thickness index (mm/m^2)	5.0 ± 0.8	5.3 ± 0.4	NS
LV posterior wall index (mm/m^2)	5.3 ± 0.7	5.3 ± 0.4	NS
LV ejection fraction index ($\%/m^2$)	42.5 ± 4.4	48.9 ± 5.2	< 0.001
Stroke volume index (mm/m^2)	40.4 ± 7.1	43.6 ± 7.4	NS
LV mass by M–mode index (mm/m^2)	82 ± 16	59 ± 11	< 0.001

LA — left atrium
LV — left ventricular
NS — difference not significant

The female student middle–distance runners were older, taller and heavier — all statistically significant. But it is interesting that their left ventricular cavity dimensions and septal thickness are no greater than the dimensions of the good young runners.

The good young runners had greater indexed dimensions of the nordic root diameters and left atrial size. The left ventricular mass of the student runners was greater.

Our data are in accordance with Maron [12] review that the heart dimensions of sportsmen are within the range of norms.

There have been several explanations for the increase of student runners left ventricular mass and for no increase in the left ventricular cavity dimensions.

The well-known study by Morganroth et al. [14] describes the accentric hypertrophy (normal wall thickness, increased left ventricular enddiastolic volume) in swimmers and long distance runners but mentions no increase of left ventricular enddiastolic volume and increase of the wall thickness in shot putters. Morganroth et al. [14] think that these different changes are determined by different training programmes. Most of our student runners studied physical education at the university and had not only aerobic but also burst anaerobic activity (jumping, sprinting and so on) exercises in their study programmes. Therefore the student runners have a pattern of pressure overload LV hypertrophy.

CONCLUSION

The echocardiographic evaluation of LV dimensions and wall thickness failed to reveal significant differences between the groups of beginners and good young middle distance runners.

The evaluation of LV dimensions of student runners was not different from that of good young runners.

But the students of the faculty of physical education have many exercises in the anaerobic regime and therefore they have a pattern of pressure overload LV hypertrophy.

No athlete showed any evidence of left ventricular pathological hypertrophy or pathologically abnormal measurements.

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AEROBIC AND ANAEROBIC WORK CAPACITY AND INDICES OF CARDIORESPIRATORY SYSTEM DURING GRADUATED LOADS IN BOYS FROM 10 TO 18-YEARS OF AGE

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INTRODUCTION

Several reports about the maximal aerobic power in relation to age and sex were published [3, 6, 7]. The dynamics of maximal oxygen uptake in various age groups were first described in classical studies of Robinson [10] and Åstrand [3]. Relatively few investigations have been carried out on the determination of anaerobic work capacity and on a more detailed evaluation of factors in relation to performance capacity in children [2].

The purpose of the present paper is to determine aerobic and anaerobic performance capacity in Estonian boys and to study the relationships between various indices of physical work capacity during graduated physical loads on the bicycle ergometer.

SUBJECTS AND METHODS

Our subjects were 84 boys performing 2 hours of physical exercises weekly according to the school physical education program. They were divided into 4 groups: 10–11 (n = 21), 12–13 (n = 20), 14–15 (n = 22) and 16–18 (n = 21) years of age.

The experiments were performed on the bicycle ergometer with electrically breaked system. The initial load was 50 W and it was increased by 50 W after every two minutes until the boys were not able to maintain the constant pedelling rate 70 rpm, or the heart rate was over 170 beats per minute. After that a one-minute lasting load with the maximal pedalling rate was used. Earlier studies [4, 9] showed that the tests with rapid increase of the loads (2–3 min) gives a good information about the aerobic and anaerobic capabilities of the subject.

The O_2 and CO_2 analysis was performed by using the rapid gasanalyser of paramagnetic and infrared systems, respectively. The expired air was collected into Douglas bags during the last 30 sec of each load and during 10 minutes of recovery.

During the whole experiment the heart rate was monitored using electrocardiographic method. The blood pressure was determined by using the indirect Korotkov's auscultatory method.

For the determination of maximal expiratory and inspiratory airflow rate the pneumatochometer was used.

The anaerobic alactic power of muscles was determined by the method described by Margaria et al. [8]. The oxygen debt was calculated on the basis of excess O_2 uptake during a 10-minute period of recovery.

RESULTS

The main anthropometrical data and indices of respiratory system of boys are presented in Table 1. It follows from these results that the maximal air flow rate and the vital capacity rise with age. There are no differences between the values of maximal airflow rate during expiration and inspiration in boys aged from 10 to 13 years. With the age of 14 years the values of inspiratory airflow rate are statistically significantly higher.

Table 1

Antropometrical data and indices of respiratory system of boys $\bar{x} \pm S_{\bar{x}}$

Age group (years)	Number of boys	Height (cm)	Weight (kg)	Vital capacity (ml)	Expiratory airflow rate (l/sec)	Inspiratory airflow rate (l/sec)
10–11	21	146.4±1.3	40.3±1.9	2267.6± 64.2	3.2±0.1	3.2±0.1
12–13	20	160.5±1.6	46.3±1.6	2983.3±142.1	4.0±0.1	4.1±0.2
14–15	22	170.9±1.8	58.8±1.9	4026.0±148.2	4.8±0.2	5.2±0.2
16–18	21	174.4±1.4	64.3±1.9	4474.4±108.9	5.4±0.1	6.4±0.2

The heart rate values recorded during the experiment are summarised in Table 2. The heart rate at a given load is lower in boys aged 14 to 18 than in younger groups. The maximal heart rate during the end-spurt is the highest in 12–13 year old boys, the mean values being 195.4 beats per minute.

The changes in the diastolic blood pressure during work are insignificant, the systolic blood pressure at a given load increases more in older boys than in younger. The increase of the pulmonary

Table 2

Values of heart frequency during progressive work test ($\bar{x} \pm S_{\bar{x}}$)

Age, years	I	50 W	100 W	150 W	200 W	250 W	Spurt
10–11	94.2	137.5	152.0	172.0	–	–	190.1
n = 21	1.9	3.1	3.0	2.6			2.1
12–13	100.8	135.1	142.1	161.2	171.6	–	195.4
n = 20	3.0	1.6	1.9	2.5	2.9		2.0
14–15	92.0	117.4	125.2	138.7	153.0	158.3	188.5
n = 22	2.8	2.3	2.4	3.4	3.6	2.4	2.2
16–18	95.5	119.9	128.9	140.1	154.4	163.6	186.4
n = 21	2.9	3.2	3.3	3.3	3.6	3.7	2.1

ventilation during the submaximal work is similar for all groups, the highest values of maximal pulmonary ventilation are observed in 14 to 18 year old boys.

The oxygen uptake during submaximal loads at a given intensity is similar in all groups, during the maximal load it is higher in older boys. The oxygen uptake per kg of body weight at a given submaximal loads decreases with age. The values of maximal oxygen intake per kg of body weight are very similar in all group ($P > 0.1$). (Table 3).

Table 3

Indices of aerobic and anaerobic work capacity in subjects ($\bar{x} \pm S_{\bar{x}}$)

Age, years	$\dot{V}_{O_2}$ max		O_2-debt		Anaerobic alactic muscular power		Maximal power W
	l/min	ml/min·kg	l/min	ml/kg	m/sec	kGm/sec	
10–11	1.675	43.1	1.93	30.2	1.07	43.2	121.8
n = 21	0.090	2.4	0.098	3.2	0.02	1.7	3.9
12–13	2.005	42.2	1.774	38.6	1.25	57.3	138.1
n = 20	0.097	1.7	0.113	2.1	0.04	2.3	4.1
14–15	2.715	46.0	2.781	46.8	1.41	82.9	198.2
n = 22	0.151	2.2	0.227	3.4	0.03	3.6	7.4
16–18	2.801	44.6	2.936	45.9	1.41	90.3	257.2
n = 21	0.194	3.0	0.248	3.8	0.02	3.1	5.5

The maximal work rate during one-minute lasting end-spurt increases significantly with age, the highest values of rounds per min and the performed power being 132.4 rpm and 297.2 W respectively. The oxygen debt and anaerobic alactic power of muscles increase from 10 to 14–15 years, the highest values, 46.8 ml/kg and 1.41 m/sec respectively, are recorded in boys aged 14–15 years (Table 3).

DISCUSSION

Gadhoke et al. [5] have shown that the oxygen uptake and pulmonary ventilation at a given work load are not related to age. It is in agreement with our results. The oxygen uptake per kg of body weight during submaximal loads is related to the age while no differences are observed during the recovery period. The values of maximal pulmonary ventilation increase with age from 10 to 14–15 years while almost equal data are obtained in boys aged 14–18 years. The comparable values of $\dot{V}_E$max in boys the same age have been reported by Robinson [10] and Gadhoke et al. [5].

The maximal aerobic power increase can be found in boys aged 10 to 14 years, equal values are determined in boys of 16–18 years old. These results are very similar to those published by Åstrand [3] and Tichvinski [13] whereas in studies of Robinson [10] and Seliger et al. [11] $\dot{V}_{O_2}$max is related to age up to 18–19 years. The maximal oxygen uptake per kg of body weight is practically equal in all age groups which agrees with several reports [3, 11, 12].

The maximal aerobic power of Estonian schoolboys is closely similar to the data reported for Canadian children [12], for Australian schoolboys [1], for children of Leningrad [13] and for Czechoslovak boys [11]. The American and Swedish results are higher [3, 10].

It is interesting to note that in spite of the same $\dot{V}_{O_2}$max, the same indices of oxygen debt and anaerobic alactic power of muscles: the 16–18 year old boys are able to perform higher maximal work output on the bicycle ergometer than boys aged 14–15 years.

It follows from our results that the correlations between the maximal aerobic power and various indices of cardiorespiratory system are not always similar in various age groups. The values of $\dot{V}_{O_2}$max are significantly related to maximal pulmonary ventilation of boys aged 10 to 18 years (r = 0.83 to 0.93), whereas the correlations between $\dot{V}_{O_2}$max and maximal airflow rate become significant in the age between 12 and 18 years (r = 0.42 to 0.80). It seems that the functional state of respiratory muscles determined by pneumotachometer method plays a great role for the maximal aerobic power of boys aged 12 years and older.

The values of maximal oxygen uptake and heart rate during submaximal loads are significantly related in boys from 14 to 18 years (r = −0.47 to −0.63). In younger boys these correlations were not observed. It shows that the indirect methods for estimation of $\dot{V}_{O_2}$max by using submaximal heart rate values are more valid for 14 year and older boys.

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ON THE DEVELOPMENT OF STRENGTH QUALITIES OF ADOLESCENTS IN RELATION WITH BODY COMPOSITION, BIOLOGICAL RIPENESS AND SOMATOTYPE

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In raising young generation one of the most actual problems is finding out the regular data of physical development of schoolchildren. During this period intensive endocrinological and morphofunctional changes take place in the body, body constitution is formed, physical qualities-strength and skills develop, the relations between somatic components change. The study of age peculiarities of changes in these qualities is necessary for establishing the allowed training loads.

The functional activity of body composition can be divided into two parts: active body mass and fat. The active body mass is directly related to various physiological qualities but also to man in different situations where strength is needed [1, 2, 4].

At the first stage of the investigation the relationship between the dynamics of the active body mass and the strength of the adolescents was studied. The active body mass was estimated according to specific gravity [3]. Strength was estimated by other tests. 855 pupils from Tartu schools aged 11 to 18 were studied. Out of them 261 went in for sports and 594 did not. The number of young sportsmen in all the age groups was 20–30 on an average, the number of non-sportsmen was 80–90.

Figure shows that maximum development of strength of the main muscle groups of young non-sportsmen and young sportsmen usually takes place between 14 and 17 years of age. The period of maximum development of the active mass of children who go in for sports precedes the period of maximum development of strength. The speeds of development of active body mass and total strength coincide, thus we suppose that the development of strength of non-sportsmen is carried out mainly on account of an increase in the muscle mass whereas in the case of young sportsmen an important role is played by the changes in the nervous-muscle system — nervous–coordination relations, in biochemical qualities of the muscles, nervous regulation of the work motor units. The above mentioned factors have a great influence on the mechanism of strength development of a developing body which experiences active muscle activity.

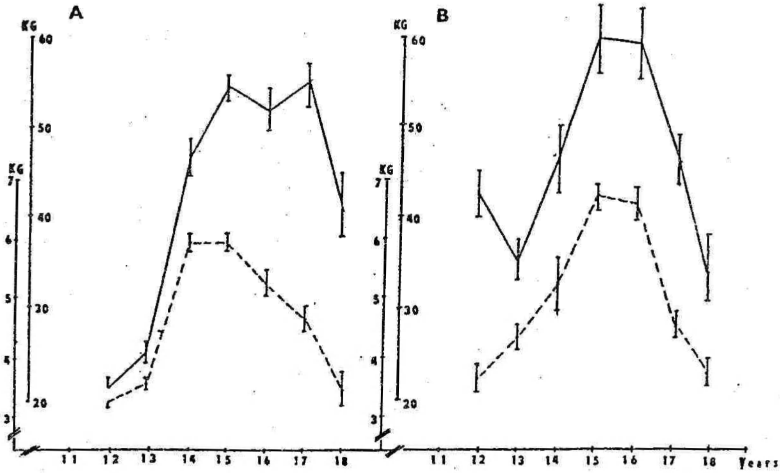

Figure. Yearly increase of active body mass and absolute strength in non-sportsmen (A) and sportsmen (B)
———— absolute strength; ------ active body mass

The second task of the investigation was to find out the peculiarities in formation of strength qualities of the adolescents in relation to somatotype after 2 months of physical training. 3 experimental groups were formed for ages 12–13, 14–15 and 16–18, with 15 to 20 people in each, and also 3 similar control groups. The following estimates of strength were studied: total absolute strength, total relative strength, tolerance of hands, legs, strength. The level of sexual development was estimated according to a 5-grade system of Tanner [6], that of somatotype–according to Sheldon [5].

In all age groups (in the case of adolescents undergoing training as well as those who do not) a statistically relevant positive dependence between the total absolute strength, tolerance of legs and hands was noticed. The positive relation between the level of and strength tolerance of hands was evident only in the case of older adolescents of the age of 16–18.

After 2 months of hard training the increase in strength qualities was bigger in the case of those more adolescent. Evidently there exists a regularity: the younger the sportsmen, the bigger are the differences in increase of strength qualities on the same level. The same regularity is true for non-sportsmen. The statistically relevant difference ($p < 0.05$) was after two months of training. To observe the growth in strength qualities of persons of the same age an experimental group was set up, aged 12–13, and a control group-also aged 12–13. At the age of 16–18 only the estimates of total absolute strength were higher for the persons with higher level of biological development.

The scientific experiment also showed that a number of regular phenomena exist in the development of strength qualities also in the group of boys with different body constitution. All the estimates were higher in the case of boys with mesomorphal constitution. There was a statistically relevant difference ($p > 0.05$) between the boys with mesomorphal and those with ecto- and endomorphal types of constitution in total absolute and relative strength. The strength qualities of boys with ectomorphal type of constitution were higher than those of boys with endomorphal type of constitution. An exception was the estimate of strength tolerance of legs which was higher in the case of boys of endomorphal constitution of 12–13 and 14–15 years of age than in the case of boys with ectomorphal type of constitution.

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THE DISSOLUTION OF POLARITIES AS A MEGATREND IN POSTMODERN SPORT[1]

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As a means of expression and identification, sporting practices are deeply rooted in everyone's individuality. However, they are also influenced by impersonal factors such as the media and the rapid evolution of technological societies. In a multiplicity of forms and in its most complex ramifications, sport is interwoven with the world of education and health, work and leisure, communications and business, art and culture and, of course, politics and international relations [52]. Sport, especially the high performance sport that I would like to discuss today, is marked by the transformations and innovations specific to a period that could be described as "postmodern".

In 1970, Kavolis defined the postmodern personality as one "characterized by the sense that both polarities of a great many [...] dilemmas are contained [...] within one's experience" (p. 445). Almost two decades later, deconstructions of such dilemmas have been noted in many areas. In the arts, pure ecclecticism and pastiche are the prevailing styles [46, 55, 65]; in architecture, the ancient and the modern are mixed and traditions superimposed [25, 27]; in fashion, the abstract mingles with the concrete, the artificial and the natural are blended together [22]; in religion, dogmas crumble and rapprochements are operated [59]; in politics, systems are amalgamated and traditional divisions are disappearing [37, 77]; in the media, facts and fictions are merged [26, 33, 85]; and finally in social theory, structuralisms seen in the modern period, be they DeSaussurian, Lévi-Straussian or Parsonian, are abandoned in favor of deconstructionist and pragmatic approaches [2, 19, 36, 42, 45, 54, 78].

What I would like to suggest today is that, as a cultural pro-

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duction, sport is also imprinted with this general impulse toward a dissolution of polarities. Further, I would like to suggest that this megatrend is directly linked to the ethical crisis facing high performance sport today. In order to better understand this problematic, I will situate it in the line of dissolutions affecting postmodern sport; dissolutions which mainly concern dualities such as male versus female, work versus leisure, universal versus particular, and self versus body.

MALE AND FEMALE

When various societies began to tolerate sporting practices among women, the latter had no choice but to integrate a world of sport already built by men, for men [17]. Some criticized this world and attempted to change it so that it would better correspond to women's experience [8, 9, 10, 32, 39], but without much success. An "androcentric" [7] value system is invading women's high performance sport and women athletes are giving more and more emphasis to traditionally masculine attributes such as power and strength, and values such as specialization and productivity [31]. In postmodernity, a blurring of the genres is taking place and male and female athletes come to exercice, train, and compete quantitatively and qualitatively in the same ways. It is also in the same ways that they dress for sport and prepare their bodies for competition.

From the popular movement of sport and fitness is emerging a new ideal-type of body for the woman. This ideal-type combines several cultural antitheses: stength with beauty, muscularity with slimness, firmness with softness of the curves [62]. Women are "rebuilding their bodies out of muscle" [53] and their power and hardness prepare them for sporting experiences similar to that of their male counterparts. For example, women reach the top of Mount Everest; they have their own rugby, ice hockey, and soccer teams [73]; they belong to professional volleyball, basketball, or football clubs [65, 69]; and they earn a living as tennis players, golfers, cyclists, boxers, or bodybuilders [53, 67].

LEISURE AND WORK

A second duality that tends to disappear is that of work and leisure. In modernity, work strengthened the conscience while leisure practices facilitated impulses [44]. In postmodern life, however, not only the concept of leisure society becomes a utopia (i.e., leisure time is decreasing instead of increasing [35], but leisure itself becomes work.

In the sport "industry", training machines become labor-making devices [41], and impulses are harnessed into endless repetitions. Work values such as standardization, Taylorization, impersonality, rationality, efficiency and productivity have invaded the world of sport [51]. Sport becomes alienated labor [5] or commodity [30]. The athletic body is bought, molded, exploited, excanged, sold, or discarded. The body becomes a means of production that can be sacrificed for the product. The human machine is appropriated by the political-economical system and the search for solutions to such problems as stress, violence or injuries in sport is granted to the scientific and medical communities. In that perspective, when the athletic body is damaged, efforts are not geared to change to sport or the attitudes of those who participate in it but to quickly repair the body and return it on the production line. Furthermore, when this human machine becomes obsolete, it is replaced by less-human, high-tech versions of the body made possible by postmodern technology (i.e., drugs, diets, hormones, prostheses, implants, transplants, plastic surgery, etc.).

This obliteration of the work-leisure opposition entails a gradual disappearance of another distinction: that made between amateur and professional athletes. In postmodern societies, the concept of amateurism vanishes and high performance athletes come to see themselves as workers entitled to a minimum of social benefits in exchange for the services they offer [75].

PARTICULAR AND UNIVERSAL

A third polarity which is dissolving is that of the particular versus the universal. Simply, the particular becomes universal through communications and mass media. In the global village which our planet is becoming, the sporting news, fashions, techniques and practices are transcending geographical frontiers. For example, professional sport is following international market laws and Americans are playing basketball in Italy or practicing baseball in Japan. Sweden has its own American Football League and Russians come to play hockey in Canada [16, 23, 47]. In traditionally amateur sport, there is a genuine "planetization" [52] of competition. International sport federations are consolidating themselves and multiplying in number; international commitees and multi-sport organizations are increasing in strength; and international games as well as world championships are growing in scale.

The universalization of sporting practices is also translated by the gradual disintegration of barriers such as those relative to race, ethnicity, age or handicap. More and more individuals from ethnic or racial minorities are excelling in sports which they could not practice before. High performance sport is not the exclusive privilege of the youth anymore, as age categories are rapidly increasing in number at national and international competitions [57, 61, 76]. Similarly, on a world scale, the wall separating high performance sport and physically or mentally challenged individuals is starting to collapse [70, 83].

To summarize up to now, I could say that the postmodern era and the trend toward the dissolution of polarities which characterizes it have brought an enhanced value on leisure and sporting practices of women as well as a great number of particular groups. Paradoxically, it is the newly found fascination for such practices which is leading them to disappear or, at least, to lose their identity. Indeed, the "male" sport model is absorbing the "female" one, work values are imposed during leisure time, and the ideology of the economical, technological and athletic elite is shaping the sporting practices of the particular groups making up our planetary village. This type of paradox is also present in the postmodern situation of the human entity. As distinctions fade between the self and the body, the body becomes so important that the self attempts to appropriate it.

BODY AND SELF

The self had been lost in the structures of modernity [40], but it struggles to return in postmodernity. As for the body, it is more and more engulfed in the field of social power. Let me provide brief examples from epistemology, ideology, technology, and semiology, which speak to such subordination of the body to the postmodern apparatus of power.

Epistemologically, the postmodern body moves at the center of subjectivity. The self in touch with the body, the self caring for the body, that's what sport is said to offer. Through sport, the self becomes conscious of the body, the self is embodied, exteriorized [68]. Not only bodily practices, but the body itself becomes a sign of the self. Enhancement of the outside is undertaken in the service of the inside, and the body image becomes not only a symbol of physical health, but of mental health as well [28]. By conveying the idea that spirit can shape matter, postmodernity tends to reduce surface and depth to a relative sameness [14]. The postmodern self is only skin deep.

Ideologically, the "body to excess" [49] becomes the perfect analogue to the general economy of excess structuring postmodern societies [1]. The body is inscribed by the signs of the fashion industry and the arts. Skin itself becomes clothing for the body, and body parts become artistic creations. The body, especially the impossibly ideal athletic body, holds a signal position in the somatic culture as locus for billions of dollars of commercial exchange and a site for moral action [18, 77]. In publicity and marketing, the glorification of the perfect body condems the natural body to be shattered in parts that are bought, sold, exchanged, replaced, molded, trained and reified. Sports media provide a particularly compelling example of how body parts (e.g., arms of pitchers, legs of runners, feet of soccer players, etc.) undergo alienation and commodification to excess. The orgy of body parts which floods our societies reveals how media present the plastic-fantastic body as a reality, and the natural body as a fraud of the second order [13, 50].

Technologically, the natural body becomes an object superfluous to the operation of a postmodern sport system. The natural body is covered with aerodynamically designed clothes; shaved foor speed; locked into ankle, knee, arm, and neck braces; invaded by diuretics, growth hormoners, high-calory foods, vitamins, carbo-hydrates, "pure" blood, and multiple drugs; divided in parts to be separately trained and shaped with computerized machines; and divided in pieces that are sometimes thrown away (e.g., plastic surgery) or replaced by artificial versions (e.g., teflon articulations). The natural body disappears. In modern times, the image was modelled after the human body. In postmodernity, the reverse is true: the human body is modelled after the image. Consequently, the type of body which is glorified is the one that looks inhuman. For example, an athlete recently confided: "You should see my calves since I took up triathloning. People behind me in supermarket checkout lines whisper: They must be implants.' It's incredibly gratifying" [63]. In postmodern societies, high performance sport is more and more contingent upon computer-revealed genetic potentialities (e.g., physical and psychological), absorption of chemical substances, and individualized diet and training. Technologically, the reality of the natural body becomes that of "ultra-refuse" [49].

Semiotically, the body constitutes a sign system that is processed through the imperatives of postmodern social power. Mediatization of the body, publicization of the skin, and exteriorization of body organs match a social system that depends on the outering of body functions (we need only to think of Walkmans as ablated ears, *in vitro* fertilization as alienation of the womb, or computers as external memory). In our civilization of signs [4], objects are consumed in their sign form and their meaning is derived from their position in a system of differentiation [20]. In postmodern somatic culture, the body is seen as a sign of the self: it constitutes identity. The body experiences its immersion in nature when it grows old or sick. Nature mercilessly contradicts the human dream of self-mastery, freedom, or infinitude. If, as a sign, the athletic body fascinates, it is because it signifies this dream. The perfect body fabricated and glorified by the sport institution and the media [58] symbolizes infinitude and self-mastery: a body that belongs not to nature but to a self. However paradoxical, it is in this vision of a "rational self" controlling bodily existence that enters the computerization, medicalization, and pharmacologization of the athletic body. In such vision, the alienating power of nature is replaced by a power that is not only technical, but which requires the infrastructure of an entire social, economic, and political system [6, 20, 24]. In many ways, this corresponds to what Heinilä [38] has described as the nightmare of "totalization".

ETHICAL AND UNETHICAL

From the analysis presented so far, I would like to extrapolate and suggest that the dissolution of the self-body, particular-universal, leisure-work, and male-female polarities are but a few of the multiple dissolutions taking place in postmodern sport. I would also like to suggest that this megatrend is reflected in the ethical crisis affecting postmodern societies. For instance, the emergence of totalization means the transformation of political, economical, medical and scientific systems in what Foucault calls a "government of the body" (cited in Turner, 79]. By taking over bodily ethics, this government brings it on shaky grounds. For example, the definition of what is life, death, health, normal, natural, or ethical depends on the political group in power, the economy, technology and medical discoveries. The prolongation of life is questioned in period of recession; the workers' consumption of cafeine, fluoride, aspirin, vitamins, hormones, antibiotics, or synthetic food is considered normal when the goal is increased production; and the rent or sale of one's own organs (e.g., uterus, kidney) is considered ethical when medical science reduces the negative consequences usually associated to the practices.

Such a dissolution of the line separating the ethical from the unethical in the general domain of the body has obvious repercussions in the domain of sport. The same political, economical and medical considerations come into play, even justify the technological modifications of the body or certain forms of cheating, doping, or violence in sport. The typically postmodern "everything goes" ideology invades sport. For example, athletes can access an increasing number of performance enhancing chemicals [72] and violent incidents are multiplying [21, 29, 43, 48], even in traditionally non-contact sports [34, 80].

With regards to the particular problems of violence, cheating and doping in sport, what makes them specifically postmodern is not their existence since historians have demonstrated their presence even in the Games of Antiquity. But firstly, is it their epidemic proportions. There is a clear difference between the modern and post-modern periods with respect to the frequency of known incidents of doping, violence and cheating [56, 60, 71]. Secondly, it is their mediatization: while in pre-modernity the sport institution managed to mask these problems, nowadays they are publicized (in most cases) and even at times used for commercial purposes [48]. Thirdly, it is the attitude of tolerance which postmodern citizens have adopted toward them. For example, the number of spectators continues to increase at an important number of sport spectacles, despite the fact that they are more and more violent [15, 81, 84]. Similarly, there have already been a few serious proposals concerning universalization of access to performance enhancing drugs [12], as opposed to universalization of their prohibition. Fourthly and finally, it is their recuperation by the government of the body, and the transformation of the ethical discourse wich concerns them into a discourse that is commercial, medical, technological and scientific. The result? Problems of violence and injuries in sport, for example, are tackled by granting money to agencies responsible for designing safer equipments. Or, attempts to solve the problems associated to doping in sport are centered on high-tech research regarding detection.

By taking over sport ethics, the government of the body gives legitimacy to the technological and scientific discourse relative to the body as well as to the ideology of a "plastic" somatic culture. This ideology incites the technological transformation of the natural body, which catalyses its disappearance. As for the "plastic" athletic body, its efficiency allows for better performances and records that are crucial to postmodern capitalist societies, where the capacity for consumption of records grows by an arythmetic ratio [79]. In fact, the conspicuous consumption which afflicts postmodern societies weighs on sporting practices and ethics in that professionalization of athletes, violence, drugs, or technological modifications of the body come to be considered as legitimate means of production and overproduction in sport. In that perspective, the natural body disappears and the athletic body is sacrificed for the spectacle, the performance, the record [18].

CONCLUSION

In this fin-de-millenium, high performance sport is witness to the dissolution of several cardinal polarities of experience wich existed in modern society. The body-self distinction, for example, is attenuated in the process of constant comparison with ideal images in the media. The borders between male and female, young and old, amateur and professional, particular and universal founder as well. I would like to suggest that while some dissolutions may be seen as potentially[1] progressive, the general trend toward collapsing oppositions and the "everything goes" ideology associated with it have contributed to the blurring of ethical and unethical practices in sport, and the transformation of the ethical discourse into a commercial, medical and scientific discourse. This has had devastating consequences for the athletes and the sport institution, particularly in terms of their subordination to a totalitarian apparatus of power: the "government of the body".

I should conclude by mentioning that the sociological understanding of postmodern sport is not exhausted, but only started by identification of its tendency to dissolve polarities. Nevertheless, this effort serves to situate what would otherwise be viewed as mere fad or fancy, as a constituent part of the ongoing process of culture production.

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[1] The potential is there when the dissolution of one polarity is not translated by is amalgamation and subordination to the other. For example, the dissolution of the male-female polarity is potentially progressive, but not if it means that women athletes simply enter an unaltered "male" model of sport.

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SKELETAL MUSCLE AND PHYSICAL PERFORMANCE CHARACTERISTICS OF RUNNERS

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INTRODUCTION

The present study was undertaken to assess the relationships between physiological and biomechanical parameters of endurance capacity, muscle fiber composition *(m. vastus lateralis)* and level of competitive results in different running distances. The physiological and skeletal muscle characteristics of 12 Estonian male elite middle and long distance runners were evaluated in the context of their race performances on "basic" and cooperative distances. From previous studies [1, 8] it can be assumed that during high intensity and short duration work involvment of fast twitch (FT) fibers is substantial and that in repeated high tension contractions muscles rich in FT fibers rapidly lose their contractile tension when compared with muscles of a high proportion of slow twitch (ST) fibers.

METHODS

Twelve male well-trained middle and long-distance runners took part in this study. The endurance capacity was measured as aerobic and anaerobic performance in laboratory veloergometric tests and race performances on track in field conditions. The dynamics of muscular performance measured in C. Bosco et al. [1] one minute vertical jumping test. Needle biopsies were taken from the *m. vastus lateralis.* Fibers were fixed with 2.5 % glutaraldehyde in 0.1 m cacodylate buffer, postfixed in 1 % OsO_4 in a cacoldylate byffer, dehydrated in graded ethanol and embedded in epon 812. Sectioning was done with AN LKB ultratome III. "Semithin" sections (1 μm) were stained with cresyl violet [11] and analysed with the microscope Leitz-Laborlux. Microphotographic enlargements (18 24 cm) of the slices were used for fiber classification and for determination

Table 1

Physical characteristics and physiological profile of the subjects group

	the values indicate the mean ± SD	
Age (years)	23.8	2.1
Height (cm)	179.6	3.8
Weight (kg)	68.9	4.0
Maximal oxygen uptake ($l \times min^{-1}$)	4.63	0.42
($ml \times kg^{-1} \times min^{-1}$)	67.5	3.7
Fast twitch fibers (% in *m.vastus lateralis*)	43.8	6.9
Mean diameter of fibers (relative units)	24.9	3.3
C. Bosco mechanical power test [1]		
Average power output ($watt \times kgBW^{-1}$) 0–15 sec	22.3	2.1
0–60 sec	19.2	2.7
Decrease of average power (%) 0–60 sec	17.9	3.0

of the smaller diameter for cross-sectioned fibers. Sections for electron microscopy were stained with uranyl acetate and lead citrate. The examination was done with an EM 100 LM (USSR) electron microscope.

RESULTS AND DISCUSSION

The parallel analysis of "semithin" sections and electron microscopical sections makes if possible to indetify three types of fibers in human *m. vastus lateralis.* Six sportsmen have more than fifty percent of fast-twitch fibers in this muscle. Kiessling et al. [7] have found that the percentage of slow-twitch fibers (type I) was 25–28 % in the untrained men before the start of the training and only minor changes were observed during the training.

The mean diameter of fiber was in good positive correlation with the content of type II fibers in muscle.

Electromicroscopical analysis makes the determination of fiber type and detection the pathological changes at the cellular level more exact.

Mammalian skeletal muscles are composed of fibers which can be classified into different types depending on their physiological, metabolic or morphological properties. Differentiation of skeletal muscle fiber types is usually done by histochemical techniques on light microscopical level (Fig. 1 and 2). The term "red, white and intermediate" has been used as descriptive designations for three fiber types on the basis of differences in oxidative enzyme activities [3]. Histochemical method used to categorize fibers into types is staining for myofibrillar actomyosin ATPase after preincubation in media of different composition, such as acid [2], alkali [12] or CU^{2+} [10]. Most histochemical methods have confirmed the existence of type I fibers (slow-twitch) and two or three subclasses of type II fibers (fast-twitch). Muscle fibers have also been categorized on the basis of a complex of features (contractility, metabolic characteristics, fatiqueresistance, cytological properties).

The differences between human muscle fiber types may not be as distinct as in other species. Gollinck et al. [5] identified only two different fiber types in human *m. vastus lateralis* stained for acid-stable myofibrillar ATPase, the slow-twitsh (I or "red") and fast-twitch (II or "white") fibers.

A useful tool to resolve these problems is to use "semithin" slices, stained with cresyl violet [11] or P-phenylene-diamine [9]. It makes possible to identify three types of fibers: 1) fast-twitch, glykolytic, IIB, "white"; 2) fast-twitch, oxidative-glykolytic, IIA, "red"; 3) slow-twitch, oxidative, I, "intermediate".

The electromicroscopical analysis (Fig. 3 and 4) makes it possible to identify four different types of fibers [4]. The most complete description of the fine structure of human skeletal muscle fibers was given by Schmalbruch [13]. It is interesting that most of the investigators have found two types of fibers in human *m. vastus lateralis* which differ only in the number and size of mitochondria [6, 14].

On the problems connected with relationships between the parameters of endurance capacity and muscle fiber composition our results support the earlier findings that the jumping test was sensitive in differentiating subjects with varied fiber composition in the vastus lateralis muscles [1, 8]. Average power output in the first 15 sec of 60 sec jumping correlated with the percentage of fast twitch fibers (Fig. 5). Higher results in distance running correlated with the aerobic capacity and power decrease in average mechanical power during the 60 sec jumping test were connected with low percentage of fast twitch fibers [Fig. 6].

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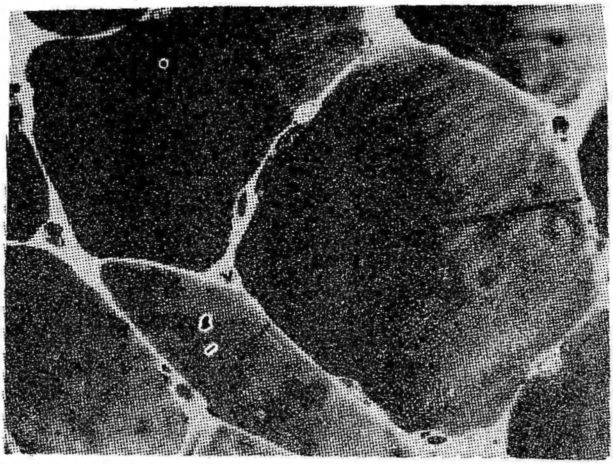

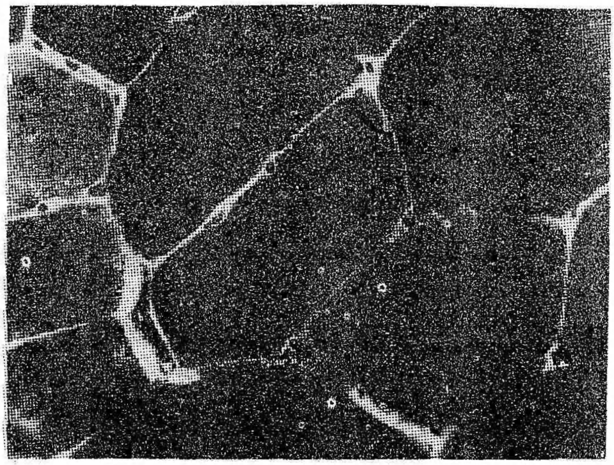

Fig. 1. and 2. Light microscopy. Cross sections.
"Semithin" slice, stained with cresyl violet.
W — white fiber; R — red fiber
Magnifications 600 ×

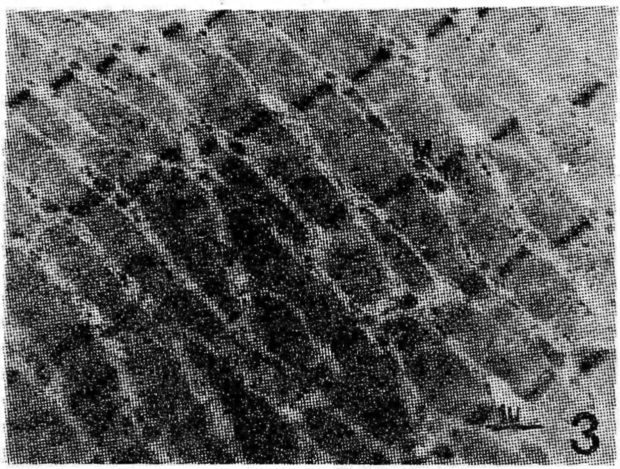

Fig. 3. Electron microscopy.
White (fast-twitch, type I) fiber
Magnification 15 000 ×

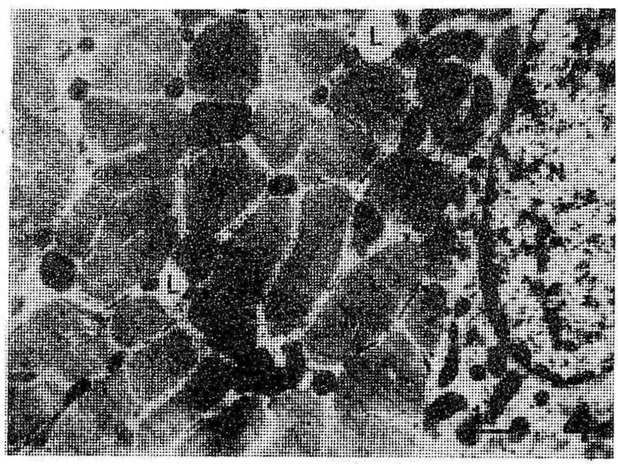

Fig. 4. Electron microscopy.
Red (fast-twitch, type II B) fiber
Magnification 19 500 ×.
N — nucleus, L — lipid droplet, M — mitochondrion,
Mf — myofibril. CAP — capillary

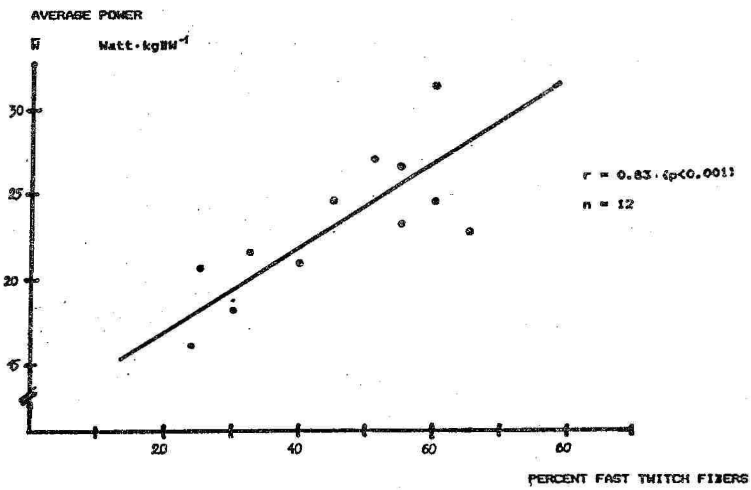

Fig. 5. Relationship between average power output calculated for first 15 sec of 60 sec jumping and fiber composition of the vastus lateralis muscle.

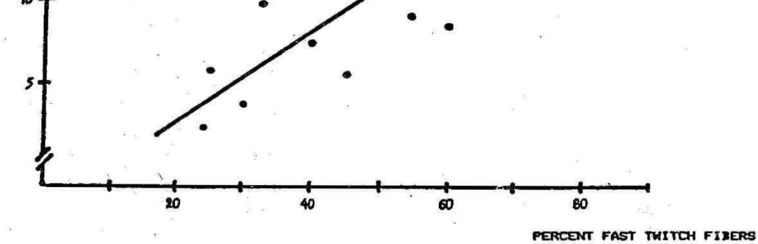

Fig. 6. Relationship between the decrease in average mechanical power during 60 sec jumping test and percent distribution of fast twitch fibers in the vastus lateralis muscle.

ON DIRECTION OF MORPHOFUNCTIONAL SPECIALIZATION OF ORGANISM OF MIDDLE AND LONG DISTANCE RUNNERS IN COURSE OF MULTIANNUAL AND ANNUAL TRAINING

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One of the most successful methodological directions in the modern endurance training is the systemic approach the basic standpoints of which are expressed in the theory of the universal system [4] and in the theory of functional systems [2]. The special preparation of a runner at any stage of preparation or level of mastership may be regarded as a system of components organized to a certain extent. At that the organizing factor (according to P. Anokhin "system forming factor") is the competition result of the athlete. From the point of view of this methodology it is principally essential that depending on the aim, the result of the observed system necessarily changes its structure in the process of perfection. The dynamics of the structure of the special preparation is expressed in the formation of the integral factors determining the integrity, certainty and stability of the functioning of the system. i.e. the basis for high-class results.

The level of the organization of the system is characterized by the ratio of the subordination and coordination connections. The subordination connections form the influence of the components of the result while the coordination ones are those co-ordinated between the components themselves. A great number of the subordination connections is characteristic of a relatively poorly organized system which is not able to guarantee high results. A highly organized system is caracterized by the presence of the adaptational-compensatory connections between the components.

Any kind of sport activities is quaranteed by the same functional systems of the organism. Such a functional universality enables one to acquire extensive adaptational changes of the organism by regular training and competition loads. While the dominating working regime, specific character of the activities and the conditions becoming gradually more and more complicated start to influence the organism towards a certain functional specialization. Due to that the increase of the athlete's special work capacity is not connected with the development of separate motional abilities but, first and foremost, with the morphofunctional specialization of the organism [34, 35]. In the endurance events it is, first of all, characterized by the perfection of the energetic systems towards the increase of the aerobic or anaerobic-glycolytic productivity guaranteeing a high level of specific endurance in long and middle distance races. It usually takes 6–10 years to achieve the above mentioned aims. From the point of view of the morphofunctional spezialization and in the planning of multiannual training the stage of the profound specialization characterized by the formation of the structure of the special physical preparation is extremely important. The latter represents a rational form of the vegetative and motor systems and grants a high level of work capacity in specific competition conditions.

For the evaluation of the special physical preparation factor analysis can be used which, by assembling a wide scale of indices into separate factors, enables one to evaluate different aspects of the athlete's work capacity. Together with the rise of the sport qualification the role of the separate factors, especially that of the leading ones, changes [27].

Three main trends can be differentiated in the dynamics of the indices of the special work capacity (Fig. 1).

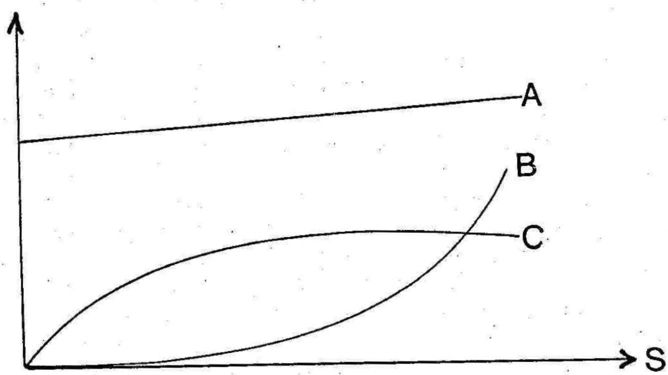

Fig. 1. The character of the dependence of the functional indices on the relative competition result S according to J. Verkhoshansky, 1985.

The first of them (A) is characterized by the linear connection with the result. Such are the integral indices of the special work capacity which are tightly connected with the result in the whole range of them. The second trend (B) demonstrates that the increase of the functional index increases essentially with the improving of the result. Such functional changes guarantee the level of the athlete's special work capacity (A) on higher levels of sport qualification. The third trend (C) is characterized by the monotonously decelerating increase of the functional indices and weakening connection with the result. Such functional changes refer to the primary influence on the results and thereafter play an essential role in the creation of the functional basis to guarantee an accelerating increase of the specific indices (B) in the athlete's special work capacity.

The structure of the special physical preparation and the morphofunctional specialization of the organism are very closely connected with the mobilization of the functional reserves of the organism. According to A. Mozzhukhin [26] the latter is expressed:

1) in the changes of the intensity and speed of the energetical and plastic processes of metabolism at the cell and tissue level;

2) in the changes of the intensity and speed of the proceeding of physiological processes at the level of organs, systems and the organism as an integer.

In the first case they are biochemical, in the second one — physiological reserves. The introduction of them guarantees the bioenergetical processes, preservation of homeostasis, co-ordination of the functioning of the motional and vegetative processes.

A. Korobov and N. Volkov [19] recommend to pay main attention to the bioenergetical factors in the development of endurance. They are:

1) power — the greatest speed of the energy production in a concrete process;

2) capacity — the amount of the energy reserves or the range of the metabolic shifts in the organism;

3) efficiency — the level of the use of the aerobic and anaerobic energy processes in the performance of a specific load.

All the above three criteria are characteristic of both aerobic, glycolytic and alactate processes. At that one should specially stress the dominating role of the aerobic processes in the energetics of biological systems [10]. Prof. N. Yakovlev [40] also assures that in case of real sports loads the compensatory role belongs to the anaerobic processes. Generalizing the modern principles of the development of endurance J. Verkhoshansky [35] comes, in principle, to the same conclusion, to the "antiglycolytic" trend of the training.

S. Kouchkin's investigations [21] of almost 500 endurance event athletes revealed that the enhancement of the aerobic productivity in a multiannual cycle is connected with three stages:

1) at stage I positive shifts are, first of all, connected with the

increase of the lung capacity and rise of the general power of the respiratory apparatus;

2) at stage II the main contribution is made by raising the power of the cardio-vascular system;

3) at stage III the system of the O_2 utilization in tissues is determining.

The qualitative difference of the stages allows one to divide them into three categories of functional reserves [8, 22]:

1) power,
2) mobilization capability,
3) economy-efficiency.

Stage I. According to S. Kouchkin [21] the adaptation to endurance loads proceeds gradually: up to the relative O_2 consumption level of 60 $ml \cdot min^{-1} \cdot kg^{-1}$ the increase of the power of the respiratory system is dominating. For this purpose exercises for the increase of the lung capacity and respiratory volumes can be used as well as for the power of the respiratory muscles and endurance. In the following the respiratory apparatus is mobilized to maintain the possibly high level of the functioning for the longest possible time. For this purpose various hyperventilation regimes are suitable. It turned out that the best form of the influence on the economy-efficiency reserves were the hypoventilation regimes by means of which the O_2 utilization in tissues increased by 7.6 %. N. Foudin [12] came to the same conclusion. The results are in accordance with G. Grimby's investigations [13] who achived a 11 % higher O_2 utilization in tissues and a 30 % faster rehabilitation in conditions of hypercapnia as compared with normocapnia.

In case of the interruption of the training or in case of overtraining the reserves mobilized last decrease first of all. Consequently, first of all economy-efficiency reserves begin to decrease and those of power are "explosively" mobilized. This confirms the return to the primary, less economical forms of adaptation. It is accompanied by the decrease of $\dot{V}_{O_2}$max prevalence of dissimilation processes, rise in the level of urea in the morning, etc.

Stage II. The $\dot{V}_{O_2}$max is considered to be the integral index of the power of the cardio-vascular system. One of the most essential factors in gaining it is the minute volume of the heart. As the minute volume is directly connected with the stroke volume and the contractility of the heart muscle it is essential to find the adequate means of training to achieve the required shifts. The practice of the modern endurance training has rather convincingly demonstrated that the best results are achieved by the succession of the use of the training means directed from endurance to speed: aerobic threshold $\longrightarrow$ anaerobic threshold $\longrightarrow$ critical speed (i.e. the speed at which the $\dot{V}_{O_2}$max is gained). Such a succession quarantees the optimum adaptational changes in the morphological and functional parameters of the heart — in the capillarization and stroke volume, contractility and capability to utilize the lactate during work and, finally, in the minute volume.

E. Pyshnyak et al. [29] have shown that in the course of the development of the aerobic endurance the tropotrophic influence strengthens while this is connected with the activation of biologically active substances and anabolic hormones forming the plastic and energetical potential during the restitution period. On the other hand, when an attempt was made to model the performance at the distance it turned out that the energetical potential was wasted inefficiently while the O_2 transport system functioned strenously. To overcome it is necessary to use the mobilization reserves which will ultimately lead to the increase of the preservation of the critical speed. The maximal strength exercises led to the increase of the aerobic possibilities against the background of a noticeable intensification of the protein metabolism while the trainings with the strength endurance trend led to the efficient restitution of the energetical reserves and the loads with the speed endurance trend — to the increase of the anaerobic capacity. Simultaneously, a decrease in the energy expenditure per unit of work was observed [29]. It occured due to expressed economization of the motional and vegetative functions. At that the main criteria of the economy-efficiency reserves are the speed of the anaerobic threshold, O_2 utilization percentage at the level of $\dot{V}_{O_2}$max, anaerobic efficiency, etc.

The specific nature of the adaptation of both the respiratory and cardio-vascular systems in the course of the multiannual training refers to the fact that the aerobic work capacity does not so much depend on the increasing inflow of O_2 to the working muscles as on the better utilization of O_2 at the cell level. Therefore, the last link in the so-called oxygen cascade (O_2 absorption $\longrightarrow$ O_2 transport $\longrightarrow$ O_2 uptake) is of special significance.

Stage III. The O_2 uptake at the cell level depends on the amount and thickness of mytochondria, their fermentative activity, concentration of the energetical substrates, myoglobine content, percentage of ST fibers, etc. These factors form the basis of the metabolic profile of the muscles [3]. While the latter, in its turn, has a noticeable influence on the so-called submaximal endurance the main indices of which are the aerobic and anaerobic threshold. The correlative connections of the different parameters of the aerobic work capacity are reflected in the factor model of the aerobic work capacity (Fig. 2).

In this model the submaximal endurance is most tightly correlated with the maximal aerobic power ($r = 0.92$) and metabolic profile of the muscles ($r = 0.83$), much more weakly with the O_2

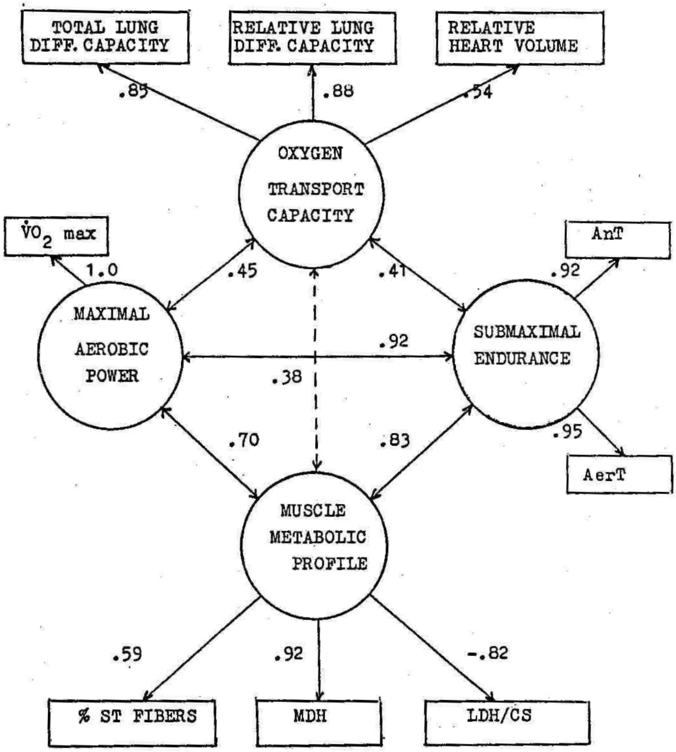

Fig. 2. The correlative factor model of the aerobic work capacity (according to S. Aunola et al., 1988).

transport capability (r = 0.41). Thus, the submaximal endurance and the metabolic profile of the muscles are the main components connected with the efficiency of the O_2 utilization at the cell level. To find the adequate training means for the development of the named component is a rather complicated task as the O_2 utilization system at the cell level is characterized by a high adaptational inertness [35]. In other words, the specifity, amount and duration of the training influences should rise in order to achieve the corresponding adaptational shifts. It is comparatively easy to gain changes in the development of the vegetative systems by usual running loads while it is much more complicated to achieve positive shifts in the indices of the speed-strength quality of the muscles and local muscle endurance by the same means. As a result, an inadequancy between the functional possibilities of the vegetative and muscle system and the inefficient development of the results may arise. To avoid it, is useful to intensify gradually the muscle work regime in these muscles which bear the main load in the given activity.

A. Konrad's and V. Selujanov's studies [18] revealed a close connection between the level of the aerobic and anaerobic threshold and the strength qualities of the slow twitch fibers. One should not forget the development of the creatine phosphate mechanism either as it quarantees the efficient transmission of energy from mytochondria to the myofibrils of the muscle both in case of the aerobic and anaerobic loads and forms a basis for the maximal speed. The above said is in good accordance with training practice which has revealed that at any stage of a multiannual training of long and middle distance runners the level of the results is determined by the basis of the aerobic endurance and speed-strength characters wherefrom the special training is started [23, 38].

Of great importance of the course of a multiannual training is the dynamics of the increase of the main components of the special work capacity. Of interest is the investigation carried out by J. Voitenko [37] where the increase of the $\dot{V}_{O_2}$max, maximal alactate power of the muscles, maximal level of the blood lactate and of the speed of the anaerobic threshold of the young highly qualified female swimmers was observed depending on their age (Fig. 3).

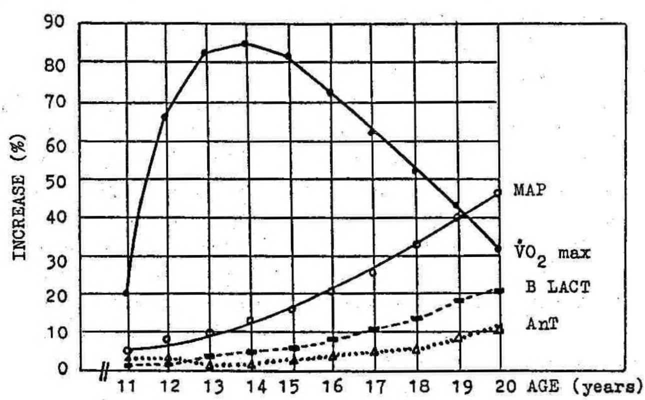

Fig. 3. Increases of the maximal oxygen uptake ($\dot{V}_{O_2}$max), maximal alactate power (MAP) of the muscles, maximal lactate level in blood (BLACT) and of the anaerobic threshold (AnT) of young swimmers depending on their age.

The comparison of the swimmers revealed that the $\dot{V}_{O_2}$max of the 11–12-year-old girls steeply rises to the age of 13–14 years. However, this is followed by a decrease during the transition period to 15–16 years in spite of the further rise of the sport abilities. Consequently, the rise in performances is achieved on account of the other components of the special work capacity. Special attention should be paid to the fact that the improvement of the swimming results in the older age groups was mostly connected with the rise of the increase of the capability of the level of the anaerobic threshold, maximal alactate power of the muscles and of that of the maximal lactate level of blood. There is every reason to assume that analogical mechanisms act in the multiannual training of runners as well. In the older age-groups and with the rise of class the role of the local procésses rises while in the formation of the high work capacity the maximal economization (high level of the anaerobic threshold) and the maximal mobilization (high anaerobic alactate power and maximal lactate level of blood) are equally important. The parallel development of these components of ability requires taking into account the phenomenon in the choise of training means.

When studying the age regularities of the development of endurance and the construction of the multiannual training of the young middle distance runners J. Travin [32] found a high correlation between the result and speed qualities at the age of 13–14 ($r = 0.603$) and at the age of 19 ($r = 0.567$). According to the same author strength qualities have a smaller influence on the result at all ages ($r = 0.528$–0.110). Obviously, the speed qualities of young runners are formed when reaching the junior age while the main contribution to the increase of endurance should take place on account of the effective development of the strength qualities.

J. Travin [32] divides the multiannual training of young middle distance runners into four main stages.

1) Preparation to specialization — age 10–12 years. Duration and playing methods as well as general physical training are dominating. The best variant in the primary preparation is when 50 % of the training time is spend on the development of training at the pulse rate of 150–170 beats per minute. The main aim is to raise the level of the $\dot{V}_{O_2}$ max. The use of various means at this stage may lead to the rise of the $\dot{V}_{O_2}$ max by 50 % which is impossible in the following years even in the course of the multiannual training.

2) Stage of specialization — age 13–15 years. At this stage the many-sidedness of the training is also in the forefront while the ability to preserve the critical speed increases. The development of the latter is directly connected with the general endurance, speed and strength.

These two stages are of essential importance from the point of view of further prospects of young runners. During the age of puberty loads at the level of the speed of the anaerobic threshold should be preferred which would quarantee the preservation and improvement of the aerobic possibilities of the young organisms. As this period is especially favourable for the rise of the oxydative enzymes [11] it should be used keeping in mind the further prospects. The post-puberty age is characterized by the rise of the enzymatic activity of muscles [30] and by favourable conditions for the rise of the anaerobic capacity [1] and for the increase of speed strength, maximal speed, anaerobic power and capacity [25]. According to the last mentioned authors, the right time to start specialization is when the level of testosterone achives that characteristic of the adults — at the age of 14.1 years on the average. However, we should be extremely careful with the trainings of the anaerobic-glycolytic trend at this period because often a person is psychically not ready to bear such loads and may exhaust one's potential too early. O. Karikosk's extensive studies [16] on the beginning of the special trainings of the world's best middle and long distance runners reveal that the best age to start them is 16–17 years.

3) Stage of deeper specialization — age 16–19 years. In addition to the earlier used training means the anaerobic-glycolytic ones are used in small amounts.

4) Stage of high class trainings — age 20–24 years. At this age the structure of the special preparation and the corresponding morphofunctional specialization of a runner are fully formed.

In conclusion we can state that in the direction of the morphofunctional specialization of the middle and long distance runners in the multiannual training one proceeds from a certain gradation of the adaptation processes. The development of the aerobic work capacity proceeds from the power of the respiration apparatus and level of the O_2 absorption followed by the power of the cardiovascular system and that of the O_2 transport and, finally, the O_2 utilization in tissues. During all the three stages the application of the functional reserves takes place: first, with the trend of power, then with that of the mobilization capability and, finally, with the trend of economy-efficiency. At the same time one has to take into account that the adaptation process begins with specific changes at the cell level which, later on, call for the secondary adaptational changes in the cardio-vascular and respiratory systems, blood, ets. The mobilization of the biochemical reserves occurs first, but in the course of the multiannual training changes in the organs, systems and in the whole organism develop more quickly.

Consequently, at the stages of the profound specialization and high class training the main attention concentrates again on the energetical and plastic processes of metabolism at the cell and tissue level which would guarantee a high level of the O_2 utilization in them. For this purpose such training methods should be used which would influence the submaximal endurance, metabolic profile of the muscles and local muscle endurance. The development of all the above mentioned components covers most of the annual training of middle and long distance runners.

In conclusion let us consider the principles of the annual training of a middle distance runner at the stage of profound specialization. The result in the middle distance running depends, first of all, on the special endurance while the specific energy production regime is glycolysis. The higher the result in the 800 m and 1500 m races the greater is the role of the anaerobic processes in the energy production during competition as compared with the aerobic processes. At the end of the distance a deterioration of the anaerobic productivity usually takes place. The reason lies in the rise of the acidity of the organism, in the accumulation of fatigue substances. On the other hand, the speed of the production of lactate and the ability of acidity tolerance are the indices reflecting the level of the speed endurance. At the same time we must not forget that high lactate concentrations begin to inhibit glycolysis and the running speed decreases. Thus, the dynamics of the rise of lactate is rather essential as well as its influence on the running speed. J. Hirvonen et al. [14] convincingly showed that in the 400 m race the winners were the athletes who could rise the lactate level during the last 100 m most of all. In principle, the situation in middle distance races is analogical. Thus, in order to improve the special endurance of middle distance runners it is necessary to try to decelerate the accumulation of the acidic products in muscles or, in other words, to increase the anaerobic efficiency. The latter is influenced by the strength and elasticity qualities of the muscles, capacity of the CP system, technique, relaxation ability, aerobic basis. Hence the essential connection between the anaerobic and aerobic work capacity becomes obvious.

The aerobic endurance is influenced by the $\dot{V}_{O_2}$max, aerobic and anaerobic thresholds, functional and metabolic economy. According to H. Rusko [31] the ratio of the absolute ($l \cdot min^{-1}$) and relative ($ml \cdot min^{-1} \cdot kg^{-1}$) O_2 consumption at running loads is equal from 40 % to 60 %. This specific feative of running ratio shows that the local processes occupy a significant place in the maximal O_2 consumption. A light body weight, high oxydative potential of the metabolically active muscles as well as the high level of the indices of relative strength contribute to the effective aerobic productivity.

So far the methodology of the running training has paid great attention to the central O_2 transport system and much less to the systems ensuring the local processes. While it could be the other wayround as the nervous-muscle apparatus and the specificity of its activities determine the status, character and trend of the specialization of the vegetative systems. Consequently, the functional unity of the vegetative systems and motor apparatus and their interconnected improvement is an essential prerequisite both in the increasing of the local muscle endurance and special work capacity. According to J. Verkhoshansky [34] the local muscle endurance is expressed in the athlete's ability to continuously preserve the strength component of motion. In the development of local mechanisms it is important to observe that the ability of the muscles themsẽlves to utilize oxygen and free fatty acids as well as to separate lactate would not deteriorate. It is indispensable to take into account the redivision of the flow of blood and the increase of its intensity in the working muscles [28, 33]. The above said underlines the necessity to direct the morphofunctional specialization of the metabolically active muscles, i.e. to improve co-ordinately their contraction and oxydative qualities. At once the question of the adequate training means guaranteering the disired shifts arises.

To solve the problem observation series N 1 was carried out in the course of which the factor structure of the result of a middle distance runner of the average qualification was determined. A complex of the indices of all the athletes under investigation (n = 16) characterizing the vegetative ($\dot{V}_{O_2}$max, speed of the aerobic and anaerobic threshold, indices of the respiratory system) and muscle system (C. Bosco et al., 1983, jumping test) [6], the tests of the maximal strength and strength gradient, of the maximal speed and jumps from the standing position — long jump, triple jump, 10-jump) as well as the morphological parameters of the heart muscle (echocárdiographical data) were registered.

The factor analysis revealed four main factors with the factor weight of 81.39 %:

1) factor of the local muscle endurance — 27.63 %,
2) factor of the central hemodynamics — 21.91 %,
3) factor of the functional stability of the leg muscles — 21.48 %,
4) factor of the maximal mobilization of the nervous-muscle apparatus — 10.37 %.

The factor analysis elucidated the relations between the result in the middle distance running and the main components of the special work capacity while the necessity to find similar relations between the structure of the special work capacity and that of the training loads is assured as well. Hence the aim of investigation series II was set as the control of the principal model of the annual training of the middle distance runner an essential part of which is the development of the local muscle endurance (Fig. 4).

In the concrete construction of the content of the training we proceeded from the so-called principle of the superposition of the training loads [34, 35]. The idea of the mentioned principle is the preferable use of certain loads at a certain training stage where they are indispensable in accordance with the logics of the

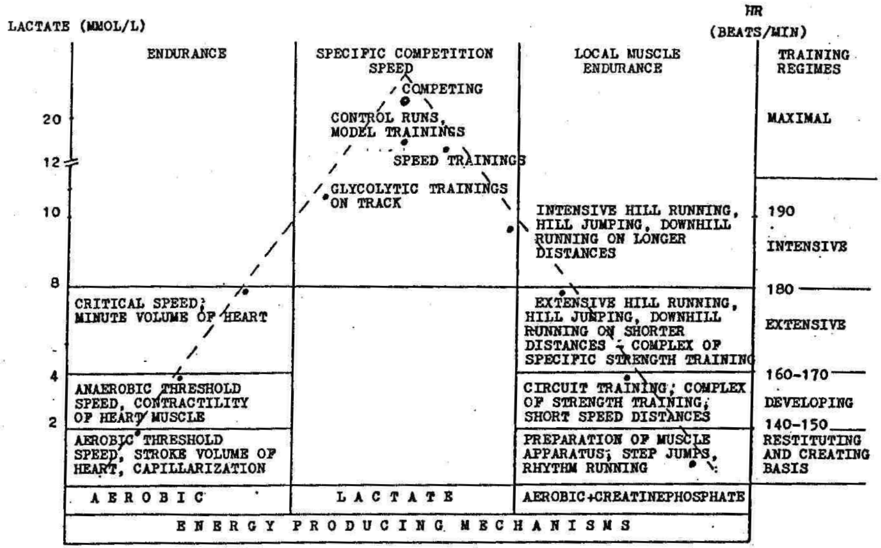

Fig. 4. Principal construction of annual training of middle distance runner.

development of the adaptation process. At that the previous loads prepare the organism for the following ones to bear. The aim is to achieve an optimum correspondence between the functional possibilities of muscles and the vegetative systems guaranteering their functioning by the planned time. The gradual rise of the specific running speed takes place in a strict correspondence with the preparation of the organism for it. While at first the trainings are intensified not in the distance speed but on the account of the specialized local muscle work. The intensification of the working regime of muscles anticipates the raising of the distance speed, thus functionally and morphologically preparing the muscle system. In this way prerequisites for the decrease of glycolysis and the preferred use of lipids, for the moderate loading of the heart muscle and favourable reactions of blood vessels are created.

The annual training of the middle distance runners is started with continuous running at the level of the aerobic and anaerobic thresholds. Together with the rise of the levels the speed of continuous running improves, the stroke volume of the heart and the contractility of the heart muscle rise. In parallel with it the use of the means of the specialized physical preparation takes place which is first and foremost directed to the development of the local muscle endurance. At the beginning of the preparation period various extensive step jumps, rhythm running are used. It is followed by a special complex of strength exercises to develop the necessary level of the maximal strength, mechanism of creatinphosphate and strength endurance. Our experiment demonstrated that the expedient connection of the above mentioned training methods can be achieved by a systematic alternation of the dominating systems, i.e. that of the endurance and strength loads. In the case of the loads at the level of capacious and accented threshold speed an attempt was made to maintain the speed-strength qualities. While during the complex of the accented strength training the volume of running means decreased. As the dominating systems are structurally granted the corresponding adaptational redivision of the energoplastic reserve preferably takes place and a possibility to adapt to different training influences occurs [24, 36]. If the alteration of the dominating systems is too fast, a permanent redivision of the energoplastic reserve from one system to the other takes place which, from the point of view of adaptation, is not an economic variant. One should also avoid cases when the influence on the dominating systems is weakened for too long a period and the deadaptation-readaptation cycles, having a rather high structural value, are continuously repeated. The latter is the amount of the structures, molecules of nucleic acids and proteins which the organism has to synthesize additionally to guarantee the given adaptational reaction. The optimum variant of adaptation is characterized by the correct ratio of the cell structures as well as by the fact that it is achieved by the minimal structural value. It is important to observe the mass and power of these structures increase anticipatorily, selectively which are responsible for guiding, ion transport and energy quaranteering [24]. The anticipatory development of the energy guaranteeing is granted in the way that the annual training cycle is started with the development of the aerobic endurance, complexes of strength training with the development of strength endurance. In the group under our observation the optimum alteration of the dominating systems was after four weeks, in the group of athletes with higher qualification it may take place after six weeks. From the point of view of adaptation it is important that after the development of a certain function it is necessary to use loads for the preservation of the gained shifts from time to time at the following stages.

The training stage described above could be considered as the basic stage of the annual training. The speed of the anaerobic threshold necessary for any middle distance runner and high as its quality may be lays far behind the specific competition speed. The solution lies in the use of the so-called rhythm running and thereafter in the extensive interval running. For this purpose, from the aspect of the local muscle endurance, a specific complex of strength training is suitable (hill running, hill jumping, downhill running). The extensive interval running may also be carried out on a flat terrain or track. In this way one can avoid excessive tension for the organism. A smooth change-over from the speed of the anaerobic threshold to the level of the critical speed which is musch closer to the specific competition speed takes place. The main aim of the use of the extensive interval running is to raise the power of the myocard and the minute volume of the heart, formation of the differentiated reactions of blood vessels, improvement of the technique on the basis of muscle strength increased at the previous stage and higher speeds. J. Holloszy and E. Coyle [15] consider it quite probable that as a result of a comparatively intensive endurance training a fourfold or even greater increase of the mytochondria content in IIa fiber type may take place. Consequently, such loads have a rather complex influence. The main requirement of such a training is: the optimum (developing, not destructive) speed and powerful motional effort. The latter is characterized by a good stretch from the hip-joint, knee joint and especially from the ankle-joint.

According to D. Conley et al. [7] an analogical construction of the training led to the gradual increase of the $\dot{V}_{O_2}$ max and economy of running of the U.S. record holder in the 1 mile race S. Scott. The increase of these two main parameters a year was 8 and 5 %, respectively, and with the top level of these indices S. Scott set the

U.S. record in the 1 mile race. The investigation showed that with the rise of the middle distance runner's performance the $\dot{V}_{O_2}$max need not necessarily fall while by a skilful construction of the training it is possible to achieve the simultaneous high level of both the $\dot{V}_{O_2}$max and the economy of running.

The trainings carried out according to the principle of the extensive interval training create a firm basis for the use of the following, most specific training means of the middle distance runner — for the use of the intensive interval and repetition running. In addition to it, at the stage of the special preparation control running [17, 20] and model trainings [5, 9, 39] are used. An expedient connection of the extensive interval training and running modelling competition contributes to the gain of the optimum relations between the muscle and vegetative systems.

The experiment revealed that the use of the above model guaranteed a statistically reliable rise of the results ($P < 0.05$) as well as reliable shifts in the indices reflecting the main special work capacity. As the training loads grew gradually and continuously the dynamics of the work capacity was similar. Such a graduality was achieved in the way when nobody prepared specially for the winter indoor competition, i.e., in fact, the one-peak way of the training planning was applied.

In conclusion we can state that taking into account the adaptational regularities of the organism, peculiarities, of the mobilization of different functional systems, specificity and influence of the training means in the annual training of runners enables us to take the athlete's organism as a system to a qualitatively new, higher functional level by the planned time. It is characterized by the adaptational-compensatory connections between the structural elements of the sports performance and preparation, with their stability. As a result the co-ordination connections prevail over subordination ones while the structure of the special preparation and morphofunctional specialization of the organism are formed. Together with it the planned rise of the results is guaranteed.

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TRAINING AND DETRAINING EFFECTS ON LIPOGENESIS IN HUMAN ADIPOCYTES

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INTRODUCTION

A common effect of endurance training is the enhanced sensitivity to insulin. The euglycemic insulin-clamp technique provided evidence that tissue sensitivity to physiological hyperinsulinemia is higher in trained subjects: in athletes the glucose uptake increased more than in untrained persons; in blood FFA and glycerol levels decreased after a month of training to values equal to 63 % of normal in comparison to a decrease of 23 % before training [8]. In fat cells the rates of 2-deoxyglucose uptake and glucose oxidation [3, 4, 5, 12] as well as lipogenetic effect of insulin [9] enhance with training. After cessation of training the elevated lipogenetic activity may lead to the augmentation of the adipose tissue if there is not any corresponding contraregulation, induced by the decrease of energy expenditure due to the change in physical activity level. With the aim to study the training and detraining effects of the lipogenesis, the experiments were performed on adipocytes of the subcutaneous fat, taken from sedentary persons, active sportsmen and previous sportsmen.

METHODS

The subjects of study were 15 male persons: 4 active sportsmen in endurance events, 2 skiers and 2 rowers, 7 previous sportsmen in endurance events (3 cyclists, 2 skiers, 2 rowers) and 4 untrained persons who had never participated in systematic training (Table 1). Both active and previous sportsmen were highly qualified and had success on the international level of competitions. Among the previous sportsmen were 3 participants of the Olympic Games, including a gold medal winner. They had finished their participation in the high level of competition sports 4–8 years ago but remained physically active. All the persons were considered to be practically healthy by the results of medical examinations. Statements of informed consent were obtained from all the subjects.

Table 1

The main characterists of subjects of the study (mean ± SD)

Group	n	Age (years)	Height (cm)	Weight (kg)	% of lipid tissue	$\dot{V}_{O_2}$ max $ml \cdot min^{-1} \cdot kg^{-1}$
Active sportsmen	4	24.2±0.20	181.7±7.3	79.7±10.2	11.9±5.1	62.5± 5.2
Previous sportsmen	7	34.6±8.4	182.1±4.7	81.9± 7.8	17.9±4.8	48.2± 9.0
Untrained persons	4	20.2±1.7	182.5±7.2	81.0±14.3	17.8±4.4	45.5±11.4

The subcutaneous adipose biopsy sample was taken under local skin anesthesia from right suprailiac region between 10.00 A.M. to 10.30 A.M. after a overnight fast. The amount of the biopsy sample was approximately 200 mg of fat.

Adipocytes were isolated by a modification of Rodbell [7] technique with the aid of 25-min incubation with collagenase [1]. Glucose conversion into triglycerides were determinated according to the procedures of Carnie et al. [2]. After a 15-min preliminary incubation, the isolated cell suspension (600 μl) in fresh Krebs-Ringer bicarbonate buffer with glucose at a final concentration of 15 × 10^{-3} mol/l, $D^{14}C$(U)-glucose (13 μCi/ml in distilled water, 100 μl) were incubated with shaking at 37°C for one hour. The incubated solution was gassed with 95 % of O_2 and 5 % of CO_2. Each sample was incubated in four flasks, in two flasks with insulin at a final concentration 9 μU/ml, in two flasks without insulin. To stop the incubation, 1 ml of 1M-H_2SO_4 was added to each flask. Five ml of chloroform/methanol (2:1, v/v) was added and vortex mixed in glass-stoppered tubes, 24 hours later, the chloroform phase was retained, washed twice with 3 ml chloroform/methanol 1 M-H_2SO_4 (5:48:47, by vol) and transferred to the glas scintillation vials. Evaporation to dryness was performed at 5O°C. 9 ml toluence-omnifluor was added and the triple determination of the radioactivity content was performed by scintillation counting "MINIBETA-1211" of LKB

Wallac. Values are expressed in nmol of glucose incorporated per hour into lipids per 10^6 cells.

RESULTS

The incorporation of ^{14}C-glucose into triglyceride of isolated adipocytes indicated that the basal intensity of lipogenesis (incubation without addition of insulin) was highest in active sportsmen and lowest in untrained persons (Table 2). However, due to interindividual variability of data the differences between group values were not statistically significant ($P > 0.05$). The values over 10 μmol of ^{14}C-glucose per 1 h per 10^6 adipocytes were obtained in active sportsmen and also in previous sportsmen. All values obtained in untrained persons were below this level. Chi Square criterion showed a statistical difference in the distribution of individual values between groups. Consequently, a comparatively high level of lipogenesis can be detected in adipocytes of trained but not of untrained persons.

Table 2

Intensity of lipogenesis in adipocytes, isolated from active and previous sportsmen and untrained persons (mean ± SD)

	n	Intensity of lipogenesis (μmol ^{14}C-glucose, incorporated into lipids during 1 hour per 10^6 adipocytes	
		Basal intensity	Insulin stimulated intensity
Active sportsmen	4	13.3 ± 5.3	15.7 ± 5.7
Previous sportsmen	7	7.3 ± 3.4	7.8 ± 3.7
Untrained persons	4	5.9 ± 1.7	8.3 ± 2.2

The addition of insulin to the incubation medium induced increased rates of lipogenensis. The difference was not statistically significant in mean values. The individual analysis showed an elevation of lipogenesis rate in all untrained persons, in 75 % of active and in 71 % of previous sportsmen. The individual change was statistically significant ($P < 0.05$) in active sportsmen and untrained persons, but not in previous sportsmen (Table 3).

Table 3

Individual analysis of insulin effect on the rate of lipogenesis in isolated adipocytes

	Elevation of lipogenesis rate by insulin (% of cases)	Mean individual changes of ^{14}C-glucose incorporation into lipid in 1 hour per 10^6 adipocytes	P
Active sportsmen	75 %	$+2.7 \pm 1.2$	< 0.05
Previous sportsmen	71 %	$+0.5 \pm 0.3$	> 0.05
Untrained persons	100 %	$+2.4 \pm 1.0$	< 0.05

DISCUSSION

Our results pointed out the elevation of the basal rate of lipogenesis by training. Poehlman et al. [6] did not find these changes after a short-term training period of 22 days in man. However, in agreement with our results Tokuyama and Okuda [11] detected a three times rise of synthesis of fat acids in trained rats. The effect of insulin on the glucose transport into adipocytes and glucose oxidation turned out to be more pronounced in trained organisms as compared to data obtained in untrained organisms [3, 12]. In adipocytes isolated from biopsy samples of subcutaneous fat the stimulation of lipogenesis by insulin is only modest [6, 10], statistical significance of that is doubtful. Accordingly we did not find a statistically significant difference between mean values obtained after incubation with or without insulin. Nevertheless, the individual analysis proved the existance of significant changes in active sportsmen and untrained persons but not in previous sportsmen. Hence, the sensitivity of adipocytes to lipogenetic effect of insulin is reduced after cessation of training and competition on the international level. It was suggested that this change was essential to avoid the increase of adipose tissue after a pronounced drop in energy expenditure due to decrease in muscular activity level.

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