

# The Influences of Training on Rowers of Different Age

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## ABSTRACT

*We measured 14 rowers and divided them into two groups according to age and years of training. Our goal has been to establish the influence of several years of programmed training on the structure of the body, oxygen carrying capacity and oxidation capacity of muscle cells, the chemical composition of blood and characteristics of pulse and lactate curves in rowers. As to the structure of the body, the two groups did not differ if we equalised them according to body height. Differences existed in the determinants of oxygen carrying capacity and oxydation capacity of muscle cells. Older rowers had lower pulse at rest, higher step test index, lower pulse immediately after the step test and in the last minute of the test on a bicycle ergometer and higher maximal oxygen pulse. While at rest, no significant differences between the groups were observed in most of the analysed substances in the blood serum. With the increase of age and training period an increase of the concentration of creatinin and activity of creatin kinase and lessening of the activity of alkaline fosfatase was noted. Length of training period lowers the levels of cholesterol and free fatty acids and increases the level of triglycerides in blood serum. An increase of the activity of creatin kinase and lactate dehydrogenase and the formation of a specific pattern of isoenzymes was observed. The pulse and lactate curve flattened and moved to the right.*

## Introduction

Rowing is a branch of sport of which short general aerobic endurance is characteristic. On a 2000m long race track, the intensity of rowing is near maximal oxygen consumption of an individual with 70% of the total energy being utilised for metabolic processes of oxidation

and 30% for metabolic processes of anoxidation<sup>1</sup>. A certain form, quantity and intensity of training affects the selection of a certain enzyme energy pattern from the genetic pool of possible variants. Adequate stimuli force the selected muscle groups to improve their local oxidation capacity and increase the activity of

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enzymes that prevent the accumulation of lactates.

The favouring of certain enzyme patterns results in the occurrence of specific morpho-functional changes in the organism of an athlete. Macroscopically, adaptation changes manifest in the specific structure and composition of the body. Microscopically, they cause biochemical changes in muscle cells which can be indirectly observed by means of the chemical analysis of blood in the state of resting and after specific exertions.

**Material and Methods**

We measured 14 rowers and divided them into two groups: older (four rowers, aged 22 years, with 7 years long engagement in the sport) and younger (10 rowers, aged 17 years, with 4 years long engagement in the sport). Our goal has been to establish the influence of several years of programmed training on the structure of the body, oxygen carrying capacity and oxidation capacity of muscle cells, the chemical composition of blood and char-

acteristics of the changing of pulse and lactate curve in rowers.

**Results and discussion**

*Body dimensions*

We computed Z-values for each anthropometric variable according to fantom’s values<sup>2</sup>. As to the structure of the body, the two groups do not differ if we equalise them according to the body height (Table 1, Figure 1).

*Oxygen carrying capacity and oxidation capacity of muscle cells*

Differences exist in the indicators determining the oxygen carrying capacity and oxydation capacity of muscle cells. Older rowers have a lower pulse at rest, a higher index of the step test, a lower pulse immediately the step test and in the last minute of the test on a bicycle ergometer; they have a higher value of the maximal oxygen pulse and a lower value of the ventilation equivalent (Table 2). The adaptation of the cardiovascular system goes in the direction of increasing the efficiency of action. As regards the

**TABLE 1**  
 BODY DIMENSIONS OF TWO DIFFERENT GROUPS OF ROWERS  
 ( $\bar{X}$  AND Z-VALUES ACCORDING TO THE FANTOM’S VALUES)

	Group I (N = 4; age = 21.7)		Group II (N = 10; age = 17.5)	
	$\bar{X}$	Z	$\bar{X}$	Z
height (cm)	188.3	0	184.0	0
weight (kg)	83.6	-0.335	76.6	-0.464
Circumferences (cm):				
upper arm	33.9	0.525	33.4	0.623
forearm	28.9	0.699	28.2	0.673
thigh	58.5	-0.698	57.1	-1.014
calf	39.9	0.351	40.4	0.917
Diameters (cm):				
humerus	7.4	0.591	7.4	1.037
wrist	6.3	1.725	6.1	1.539
femur	10.5	-0.066	10.1	-0.375
ankle	8.4	2.531	8.1	2.252
biacromial	42.6	0.238	41.1	-0.016
biliocristal	26.5	-2.791	25.7	-2.898

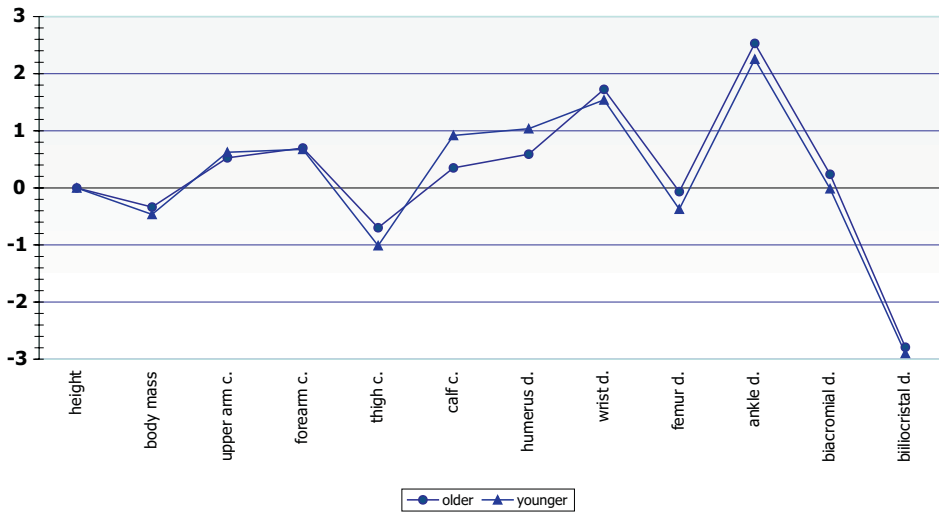


Fig. 1. Body dimensions of two different groups of rowers (Z-values according to fantom's values)

maximal oxygen consumption, the two groups do not differ, which is in conformity with the fact that maximal aerobic power of an individual is genetically determined. The high value of the maximal oxygen pulse in older rowers (Table 2) means that the difference between  $pO_2$  in blood and  $pO_2$  in muscles is maintained by muscle cells by means of an increased strength of the mitochondrion system. Owing to that, sufficient supply of muscle cells with oxygen is also ensured in a slower blood flow. However, an optimal gradient  $pO_2$  between blood and cells ensures a faster blood flow in younger rowers (max. pulse, max. oxygen pulse, Table 2).

A larger efficiency of breathing is expressed in lower values of the respiration equivalent. With maturation and years of training a tendency towards the decrease in the respiration equivalent value can be noticed; however, there are no important differences between the two groups (Table 2). The question that poses here is what is actually most efficient for an individual.

#### Analysis of blood

Analysis of blood serum at rest shows some specific traits when compared with the reference values of the normal population: the younger group has a lower concentration of triglycerides and cholesterol and a higher activity of the alkaline phosphatase; the older group has a higher value of creatine and total bilirubin. In the both groups the activity of creatine kinase is higher than the reference values (Table 3).

Higher values of creatinine are the result of a more intensive metabolic cycle of creatine phosphate and a direct consequence of a larger muscle mass in older rowers.

High values of bilirubin in the serum of some older and younger rowers already at rest and also after the loading are not clarified: are they due to an increased haemeolysis of erythrocytes or an increased permeability of the membranes of liver cells?

The second part of the experiment was carried out on 6 rowers: in the older

**TABLE 2**  
CARDIO-RESPIRATORY CHARACTERISTICS OF TWO GROUPS OF ROWERS AT REST AND AFTER  
STEP TEST AND TEST MADE ON A BICYCLE ERGOMETER

	Group I (N = 4, age = 21,7 years)	Group II (N = 10, age = 17, 5 years)
at rest:		
pulse (beats/min)	48 *	67
vital capacity (l)	6.3 *	5.3
vital capacity (ml/kg)	74 *	69
step test:		
index	152 *	104
pulse after step test	155 *	175
bicycle ergometer:		
work load (W/kg)	4.2	4.3
max pulse (beats/min)	173 * (160–190)	187 (171–204)
max. $\dot{V}O_2$ (ml/kg min)	54.4	56
respiratory quotient	1.01 (.98–1.09)	1.03 (.91–1.19)
ventilatory equivalent (MVV/max $\dot{V}O_2$ )	24.4 (22.6–27.4)	26 (20.7–31.7)
max. oxygen pulse (max $\dot{V}O_2$ /max. pulse)	26 * (25.3–27.3)	23 (19.8–27.9)

\* ... difference between groups exists

() ... minimal and maximal values

**TABLE 3**  
CONCENTRATIONS OF ELEMENTS, ENERGY SUBSTANCES, METABOLITES  
AND THE ENZYME ACTIVITY IN SERUM AT TWO DIFFERENT GROUPS OF ROWERS

	Group I (N = 4, age = 21,7 years)	Group II (N = 10, age 17,5 years)
Concentration of elements (m M/l)		
clorid	99.5 (98–101)	101 (99–105)
natrium	137 (136–138)	137.5 (136–140)
potassium	4.7 (4.5–5.0)	4.75 (4.2–5.6 )
anorg. phosphate	*1.15 (0.9–1.3)	1.3 (1.2–1.6 )
magnesium	0.74 (0.71–0.79)	0.75 (0.7–0.85)
Energy substances (m M/l)		
glucose	4.6 (4.5–4.8)	4.8 (3.9–5.7 )
free fatty acid	0.2 (0.1 –0.47)	0.17 (0.08 –0.35)
triglycerides	0.85 (0.7–1.0)	0.73 (0.4–1.3)
cholesterol	4.0 (2.5 –5.4)	3.4 (2.6–4.3)
Metabolites (m M/l)		
creatinin	99 (93–106)	89.5 (80–99)
bilirubin (all)	* 23 (9–44)	11.5 (5–28 )
bilirubin (dir.)	2.7 (2–4)	1.8 (1–3)
urea	5.1 (4.5–6.2)	5.6 (4.4–7.8 )
Enzyme activity (U/l)		
alkaline fosfataze	* 66 (47–88 )	121.5 (86 –161)
lactate dehydrogenaze	188 (168–214)	178 (166–196)
creatin kinaze	* 189 (150 –217)	159 (116–225)

... value is higher than reference one; ... value is lower than reference one;

\* ... difference between groups exists; () ... minimal and maximal values

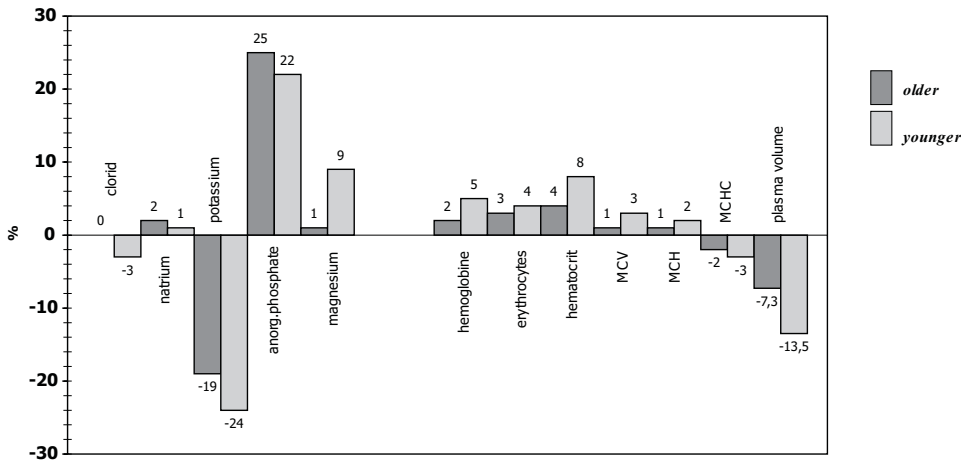


Fig. 2. Differences in concentrations of elements expressed in % (work - rest) / rest \* 100 and in hemogram between values at rest and after work load

TABLE 4  
SOME CHARACTERISTICS OF TWO GROUPS OF ROWERS

	Group I	Group II
Number	2	4
Age (years)	24 *	18.3 (17.6–19)
Years of training	8.5 * (7–10)	3.5 (3–5)
Height (cm)	185.5 (181–190)	188.7 (186–190)
Weight (kg)	88.3 (84–92)	81.9 (76–90.9)
Index of step test	172 * (150–192)	121 (111–140)

\* ... difference between groups exists

group there were 2 (age 24 years, duration of engagement in the sport 8.5 years), and in the younger group 4 rowers (age 18 years, duration of engagement in sport 3.5 years). In these 6 rowers we determined the changes in blood and serum by means of a specific test performed on a manual ergometer.

### Haemogram

Increase in the concentration of haemoglobin, number of erythrocytes and haematocrit after loading is the consequence of haemoconcentration. In older rowers the volume of plasma decreased by approximately 7.4%, and in the youn-

ger by approx. 13.5%, computed according to the method of VanBeaumont et al.<sup>3</sup>. The largest changes in the plasma volume occur in the first ten minutes of physical exertions; after that the replacing of plasma begins slowly<sup>4</sup>. Spitler et al.<sup>5</sup> did not obtain significant differences in the reduction of the volume of plasma between the trained ( Vpl = 16.8%) and untrained subjects ( Vpl = 17.3%). Similar results were obtained by Olha et al.<sup>6</sup>. The reason for the increase in the volume of erythrocytes, the quantity of haemoglobin in them, and for the decrease in the concentration of haemoglobin in erythrocyte is not clear (Fig. 2). A wide range of

**TABLE 5**  
HEMOGRAM – AT REST AND AFTER A SPECIFIC WORK LOAD ON A HAND ERGOMETER

	Group I (N = 2; age = 24)			Group II (N = 4; age = 18,3)		
	Rest	Work	Dif*	Rest	Work	Dif*
Hemoglobin (g/l)	153 (151–155)	157 (148–167)	2	151 (149–160)	159 (151–179)	5
Erythrocytes (·1012/l)	4.9 (4.8–5.0)	5.06 (4.7–5.4)	3	5.0 (4.7–5.3)	5.2 (4.9–5.8)	4
Hematocrit	44.2 (43.4–45.0)	46.0 (43.4–48.6)	4	43.6 (42.6–45.7)	47.3 (45.2–52.8)	8
Corpuscular values:						
MCV (fl)	89 (88–90)	90 (89–91)	1	87 (84–91)	90 (87–93)	3
MCH (pg)	30.8 (30.3–31.4)	31.1 (30.8–31.3)	1	29.9 (28.5–31.4)	30.5 (29.2–31.6)	2
MCHC (g/l)	346 (344–348)	340 (340)	-2	345 (341–350)	335 (332–338)	-3

\* ... dif % = (work – rest)/rest 100

the values for the majority of variables of the haemogram both while at rest and after physical efforts (Table 5) confirms the fact that athletes do not react to physical exertions in the same way, which fact reduces the possibility of prediction<sup>7</sup>.

*Elements in blood*

The elements cooperate in the metabolic process in cells as important components of the key enzymes in maintaining the membrane potential and in maintaining the volume of the intracellular and extracellular fluid; due to the importance of the enumerated functions only small fluctuations in their concentration can be expected.

The differences between the various age groups of rowers while at rest are minimal and insignificant. All values are within the limits of the reference values for adults (Table 3).

The increase in natrium concentration after maximal specific loading is negligible ( 1%) and there are no differences between the groups of older and younger rowers (Fig. 2, Table 6). The change in the concentration of chlorides is also negligible. A similar result was obtained by Olha et al.<sup>6</sup>.

Potassium is the main cell cation. The majority of authors measured the increase in the concentration of potassium in the serum during physical effort and

immediately after it<sup>8</sup>. Olha et al.<sup>6</sup> measured an increase of 45.3% in the trained and a slightly smaller increase in the untrained subjects. During exertion, the cell potassium moves into the extracellular space; this fact is confirmed by a significantly lower concentration of potassium in active muscles after exertion<sup>6</sup>. The reason for leaking of potassium from cells is metabolic acidosis<sup>9</sup> and an increased permeability of membranes of muscle cells<sup>7</sup>. Insulin, adrenaline and aldosterone force potassium back into the cells. In our research a reduction of 20% in potassium concentration after exertion (Table 6, Fig. 2) was measured. Blood was taken between the fourth and fifth minute after loading which is the reason for the occurring difference. During loading and immediately after it, Klein<sup>10</sup> measured higher concentrations of potassium, while in the sample of blood taken 3 minutes after loading the concentration of potassium was already lower than the value at rest.

The concentration of the serum phosphor is connected with the quantity of glucose which enters the cells because it forms with glucose a phosphate ester (glukose-6-phospate). Alkalosis also forces phosphor into cells; the opposite effect has acidosis. The increase in the concentration of phosphate in the plasma after exertion by 25% is partly connected with the high concentration of glucose in

**TABLE 6**  
SERUM ANALYSIS AT REST AND AFTER A SPECIFIC WORK LOAD ON A HAND ERGOMETER  
AT TWO DIFFERENT GROUPS OF ROWERS

	Group I (N = 2; age = 24)			Group II (N = 4; age = 18.3)		
	<i>Rest</i>	<i>Work</i>	<i>Dif (%)</i>	<i>Rest</i>	<i>Work</i>	<i>Dif (%)</i>
<b>Concentration of elements (m M/l)</b>						
clorid	99.5 (98–101)	99.5 (99–100)	0	100.5 (99–101)	98.2 (97–100)	-3
natrium	137.5 (137–138)	140 (139–141)	2	137 (136–138)	139 (137–143)	1
potassium	4.55 (4.5–4.6)	3.7 (3.7)	-19	4.8 (4.2–5.6)	3.65 (4.4–2.9)	-24
anorg. phosphate	1.2 (1.2)	1.5 (1.5)	25	1.27 (1.2–1.4)	1.55 (1.4–1.7)	22
magnesium	0.74 (0.7–0.78)	0.75 (0.7–0.8)	1	0.78 (0.71–0.84)	0.85 (0.8–0.9)	9
<b>Energy substances (m M/l)</b>						
glucose	4.6 (4.6)	6.8 (6.5–7.3)	47*	4.7 (4.4–5.7)	9.75 (8.4–11.1)	107*
free fatty acid	0.3 (0.13–0.47)	0.18 (0.17–0.19)	-40	0.29 (0.25–0.35)	0.21 (0.12–0.39)	-28
triglycerides	0.95 (0.9–1.0)	1.9 (1.5–2.3)	100*	0.7 (0.6–0.9)	1.2 (1.0–1.6)	71*
cholesterol	4.06 (2.7 –5.4)	2.45 (2.2–2.7)	-40	3.35 (2.8 –4.3)	2.32 (1.7–2.7)	-31
<b>Metabolites (m M/l)</b>						
creatinin	99 (97–101)	135 (135)	36	91 (81–99)	126 (115–137)	38
bilirubin-all	26.5 (9–44)	26.5 (11–42)	0*	13.6 (11–17)	0.6 (6–14)	-22*
bilirubin-dir	3 (2–4)	2 (1–3)	-33	2.2 (2–3)	1.5 (1–2)	-32
urea	4.9 (4.5–5.3)	4.85 (3.9–5.8)	0	6.5 (4.6–7.8)	6.5 (6.1–7.0)	0
<b>Enzyme activity (U/l)</b>						
alkaline fosfataze	66 (65–67)	53 (46–60)	-20	127 (98 –161)	88 (68–110)	-31
lact. dehydrogen.	176 (170–182)	226 (222–230)	28	178 (167–195)	230 (213–253)	29
creatin kinaze	180 (150 –210)	453 (400–506)	150*	159 (120–225)	353 (240–611)	122*

... dif (%) = (work –rest) / rest 100; \* ... difference between groups 20;

... value is higher than reference one; ... value is lower than reference one

**TABLE 7**  
LACTATE DEHYDROGENAZE (LDH) AND LDH IZOENZYMES ACTIVITY IN SERUM AT REST AND  
AFTER A SPECIFIC WORK LOAD ON A HAND ERGOMETER AT TWO DIFFERENT GROUPS OF  
ROWERS

	Group I (N = 2; age = 24)			Group II (N = 4; age = 18.3)		
	<i>Rest</i>	<i>Work</i>	<i>Dif (%)</i>	<i>Rest</i>	<i>Work</i>	<i>Dif (%)</i>
LDH	176 (170–182)	226 (220–302)	28	178 (168–196)	230 (214–252)	29
LDH <sub>1</sub>	0.24 (0.23–0.25)	0.25 (0.23–0.27)	4	0.25 (0.22–0.27)	0.28 (0.26–0.30)	12
LDH <sub>2</sub>	0.32 (0.32)	0.36 (0.35–0.37)	12	0.31 (0.29–0.33)	0.32 (0.31–0.34)	3
LDH <sub>3</sub>	0.28 (0.27–0.29)	0.33 (0.30 –0.36)	17*	0.25 (0.23–0.26)	0.24 (0.23–0.26)	-4*
LDH <sub>4</sub>	0.09 (0.08–0.1)	0.055 (0.05–0.06)	-39*	0.10 (0.09–0.11)	0.08 (0.05–0.1)	-20*
LDH <sub>5</sub>	0.07 (0.06–0.08)	0.055 (0.00.07)	-21	0.087 (0.07–0.11)	0.072 (0.05–0.09)	-17

... dif (%) = (work – rest) / rest 100; \* ... difference between groups 20;

... value is higher than reference one

blood, but it can also be the consequence of acidosis<sup>11</sup> and not et least of an accelerated creation of creatinine in muscle cells during exertion (Table 6, Fig. 3). Zuliani<sup>12</sup> measured the concentration of elements

in the serum after long-lasting strenuous loading; the concentration of phosphorus increased by 40%.

The magnesium ion is involved as a factor in the ATPase. Some authors mea-

Fig. 3. Differences in concentration of energy substances, metabolites and activity of enzymes between values at rest and after work load expressed in %  $(\text{work} - \text{rest}) / \text{rest} \cdot 100$

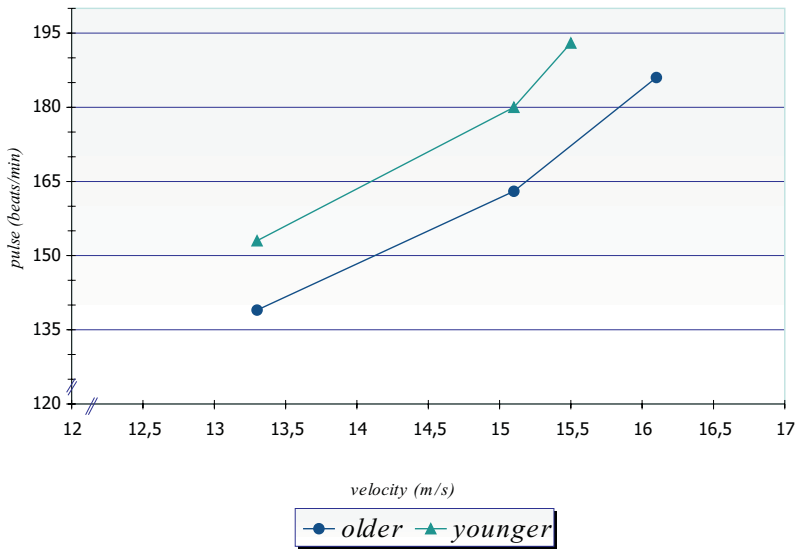


Fig. 4. Pulse – velocity curve for two different groups of rowers

sured after loading an increase of 2–6% in the concentration of magnesium in the serum (Olha et al., 1982). Others report

the decrease in the concentration of magnesium even by 21%<sup>8</sup> after various forms of loads, at various temperatures and air



humidity. An increased concentration of magnesium by 9% after a specific loading in the serum of the younger group of rowers is either the consequence of haemoconcentration (Fig. 2) or of an increased release of magnesium ions from active muscles due to metabolic acidosis.

In the serum of older rowers there are no changes despite haemoconcentration (Table 6, Fig. 2). This points to the adjustment to the requirements of training. There reduces the sensitivity of muscle cells to acidosis. The consequence is the retention of magnesium in cells, which ensures optimal activity of the enzyme of ATPase<sup>6</sup>.

#### *Energy substances and metabolites*

In the both age groups the direction of the changing of the measured values (increasing, decreasing) is the same after loading. The differences exist in the magnitude of changes; in the older, the rise in triglycerides and increase in the activity of creatine kinase is more pronounced; in the younger, the concentration of glucose increases more and the concentration of the total bilirubin decreases more (Table 4).

Carbohydrates and fats are equally important sources of energy during work.

The concentration of glucose in blood increased by 47% in the older and by 110% in the younger (Table 6, Fig. 3). The concentration of glucose in cells is relatively low in comparison with the concentration in the plasma since the transport in cells is controlled (insulin, concentration of glycogen in cells)<sup>13</sup> and since immediately after entering the cell glucose phosphorylates. A high concentration of glucose after specific loading ensures a higher gradient and hence a stronger forcing of glucose into muscle cells. The gradient is larger in the younger. The morpho-functional changes in the muscle cells of the older rowers ensure optimal passage and oxidation of the extracellu-

lar glucose also at a lower concentration of insulin and already at a smaller reduction of the concentration of glycogen in muscle cells and at a smaller concentration gradient between blood and cells.

During loading, the concentration of free fatty acids in blood can increase, remain the same or fall<sup>14,15</sup>. The mobilisation of free fatty acids from fat depots and their use in muscle cells is, nevertheless, higher during physical exertion than at rest at any level of free fatty acids in the plasma<sup>16</sup>. The concentration of free fatty acids decreased by 40% in older rowers and by 28% in the younger ones (Table 6, Fig. 3). This speaks in favour of a larger consumption of free fatty acids in the muscle cells of older rowers.

The metabolism in muscle cells is in close relation with the metabolism in adipose cells and in the liver. The dynamics of the metabolism of free fatty acids depends on the lipolysis in adipose tissue and on the oxidation in muscle cells. This dynamics cannot be established only by the determination of their concentration in the serum. This is a complex process which depends both on the activity of the hormones (insulin, catecholamine) and on how full the adipose cells are, as well on the concentration of glucose and lactates not only in the serum but also in muscle cells.

Cholesterols decreased by 40% in older and by 31% in younger rowers (Table 6, Fig. 3). This is either the consequence of a larger synthesis of the pancreatic hormones<sup>17</sup> or the result of reduced synthesis in liver cells. During prolonged exertion, the metabolism in the liver focuses above all on the supply of muscle cells with energy (glycogenolysis, gluconeogenesis, ketogenesis)? The majority of authors established, after prolonged exertion, a reduction in high density lipoproteins (HDL) which are rich in cholesterol<sup>18</sup>.

The increased concentration of triglycerides by 100% in older and by 71% in the younger rowers (Table 6, Fig. 3) can be explained with a high concentration of glucose in blood which in addition to free fatty acids influences the synthesis of triglycerides in the liver. The concentration of endogenous triglycerides (VLDL) reduces only in long-lasting intensive loadings of at least 9 hours.

**Creatinine:** creatinine phosphate transforms spontaneously, slowly and continuously into creatinine without the presence of enzymes<sup>19</sup>. Daily secretion of creatinine with urine (also its concentration in blood) is proportional to the muscle mass and represents an »individual constant«<sup>20</sup>. The concentration of creatinine increased by 40% both in older and in younger rowers (Table 6, Fig. 3), which is the consequence of larger energy turnover of creatine phosphate and increased permeability of muscle cells (acidosis, muscle fatigue).

Bilirubin is created in the breakdown of haemoglobin. Extremely high bilirubin in the older group already while at rest indicates a persistent damage to liver cells (in one rower), who, however, shows no symptoms! In large efforts there are increased haemolysis of erythrocytes and the breakdown of haemoglobin in the spleen. Due to acidosis and increased activity of liver cells, the permeability of their membranes is changed. Expected can be an increased concentration of the total bilirubin, and due to the fact that liver cells are heavily loaded by other metabolic processes, the reduction in the concentration of the direct-reacting bilirubin (Table 6).

80–90% of nitrogen excreted in the form of urea<sup>19</sup>. The concentration of urea remains unchanged after exertion (Table 6, Fig. 3). Even if during physical effort the catabolism of proteins<sup>21</sup> increases, several hours are necessary for the syn-

thesis of urea in the liver and its passing into blood.

### *Enzymes*

The activity of cell enzymes in the serum is increased after loading. The activity of creatine kinase increases the most. Alkaline phosphatase synthesises in bones (it is a typical enzyme of osteoblasts) and in the liver. In the younger group, the activity of alkaline phosphatase is high above the reference values for adults. This is a consequence of an increased activity of osteoblasts which build the bone longitudinally (growth) and at the same time adjust it by constant restructuring to sustain increased forces created by larger and larger muscle mass. The activity of alkaline phosphatase decreased after specific loading (Fig. 3). Is this the consequence of a reduced synthesis in bones and in the liver since during physical effort all energy is directed into active muscle cells?

The relationship between LDH isoenzymes in slow muscle cells is as follows: LDH1 50%, LDH2 2–7%, LDH3 3–15%, LDH4 15% and LDH5 13%<sup>22</sup>. The LDH1 isoenzyme, the most of which is in the heart muscle, catalyses the oxidation of lactate into pyruvate. The LDH5 isoenzyme, the largest amount of which is in the muscles, catalyses the reduction of pyruvate into lactate. LDH5 is catalytically more active than LDH1.

The activity of lactate dehydrogenase (LDH) increased in the both groups by 28% (Table 7, Fig. 3). This means that it is not only the consequence of the reduction in the volume of the plasma (Fig. 2). The changes in the activity of LDH isoenzymes vary after the specific loading in the two age groups: LDH3 in the older increases, while in the younger it decreases (the difference between the two groups is 21%); the decrease in LDH4 is more pronounced in older than in younger rowers (the difference between the two groups is

19%) (Table 7). As a result of training there forms an optimal pattern of LDH isoenzymes in muscle cells, maintaining an optimal relationship between aerobic and anaerobic energy power (Fig. 3).

In our experiment the activity of creatine kinase increased the most, namely by 150% in the older group, and by 122% in the younger group (Fig. 8 and 13). Great muscle effort causes a large increase in the activity of the serum creatine kinase<sup>7</sup>. Zuliani<sup>12</sup> even obtained an increase of 670% after 24 hours of exertion, however, the values return to the level of the state of rest after a few days. This is the result of an increased activity of the transfer of high energy phosphates from creatine phosphate to adenosine diphosphate.

Larger catalytic activity of cell enzymes in the serum after loading is the sign of a changed permeability of cell membranes. In normal population such changes are considered pathologic.

#### *Pulse and lactate curve*

After many years of specific training, the form of the pulse-speed curve and lactate-speed curve changes after the specific test performed on a manual ergometer. Younger rowers cannot develop such a high speed as the older ones, and they have, at the same speed, a higher pulse and a higher concentration of lactate in blood. With years of training, both curves move to the right and gradually become more flat (Fig. 4, 5).

#### **Conclusion**

The complex nature of metabolic events in the organism of an athlete are made possible by a large number of combinations – this means a large number of interactions between adipose tissue cells, liver cells and muscle cells – which reflect in the same chemical composition of blood

at rest and the same body structure. We can find the differences between older and younger rowers only after the loading. The differences exist in functional activity of the cardiovascular and respiratory system; the chemical composition of blood is also a very subtle indicator of the changes in the organism.

It were necessary to gain an insight into additional mechanisms of balancing the elements in blood – (especially the concentrations of potassium, phosphates and magnesium) and the amount of energy required to maintain their homeostasis, compared with the disturbances which occur in the activity of muscle cells due to destroyed homeostasis. Perhaps then it would be easier for us to understand how the organism (adapted to certain specific requirements of training) weighs and decides whether to use energy to maintain homeostasis or not.

There remains open the question of metabolism of free fatty acids (together with the metabolic activity of adipose cells) and their interaction with aerobic and anaerobic glycolysis. The metabolism of free fatty acids is more and more in the centre of attention since adaptation to large energy demands can only go in the direction of an increase in the energy power of free fatty acids catabolism.

All changes of the transformation of energy in the organism are a direct consequence of the intensity of the activity of specific enzyme patterns. The understanding of their interactions is the key that will open the door to new fields of the unknown.

The organism is an artist of combinations: in every situation it finds – for a certain group of elements (heart, lungs, liver, muscles, adipose cells) with varying characteristics – such a solution which enables it to achieve the largest possible complex effect at the smallest possible energy consumption.

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## UTJECAJ TRENINGA NA VESLAČE RAZLIČITE STAROSTI

### SAŽETAK

Izmjerali smo 14 veslača, koje smo podijelili u dvije skupine prema starosti i godinama treninga. Cilj istraživanja bio je utvrditi utjecaj programiranog treninga na strukturu tijela, kapaciteta transporta kisika i oksidacijski kapacitet mišićnih stanica, kemijski sastav krvi, te karakteristike krivulja pulsa i laktata kod veslača.

Nakon izjednačavanja po tjelesnoj visini, između dvije skupine nema razlika u strukturi tijela. Razlike postoje u indikatorima kapaciteta transporta kisika i oksidacijskog kapaciteta mišićnih stanica. Stariji veslači imaju niži puls u mirovanju, viši indeks step testa, niži puls nakon step testa i u posljednjoj minuti testa na bicikl-energometru te viši maksimalni puls kisika. U mirovanju ne postoje signifikantne razlike u analiziranim substancama u krvnom serumu među skupinama. Sa starenjem i godinama treninga uočava se porast koncentracije kreatinina, aktivnosti kreatin kinaze te umanjivanje aktivnosti alkalne fosfataze. S godinama treninga snižuju se koncentracije holesterola i slobodnim masnih kiselina, a uvećavaju koncentracije triglicerida u serumu, aktivnost kreatin kinaze i laktat dehidrogenaze te se formira specifični uzorak izoencima. Krivulje pulsa i laktata su plosnatije i pomaknute u desno.