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THE INFLUENCE OF PHYSICAL EXERCISE ON ALTERATIONS IN CONCENTRATIONS OF NEUROPEPTIDE Y, LEPTIN AND OTHER SELECTED HORMONAL AND METABOLIC PARAMETERS IN SPORTSPEOPLE

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Abstract. The aim of this study was to evaluate the behaviour and relationships between hormones, and metabolic blood parameters essential for energetic balance control during rest, exercise and restitution. Two groups of young boys (17 cyclists and 11 canoeists) were tested twice. Tests were performed on a cycloergometer. During the first study, anaerobic threshold was determined by a non-invasive method and in the second one - cyclists performed prolonged 2-hour exercise below anaerobic threshold and canoeists - 20-min effort above anaerobic threshold. Neuropeptide Y (NPY), leptin, insulin, C-peptide, metabolic clearance of insulin, growth hormone (GH), somatomedin C (IGF1) and glycaemia were analysed. Values of NPY and GH measured directly after exercise were significantly higher than the values of these parameters at rest, in both groups. However, effort did not cause significant changes in leptin concentration and insulin clearance in both groups. Besides, it was shown that 20-min exercise had no influence on insulin concentration in canoeists blood. In these studies significantly lower IGF1 value during restitution than directly after exercise was also noted in the cyclists group. Relations between measured hormonal parameters indicate that some mechanisms, which supply the organism with necessary energetic substrates during the effort, and accelerate the restitution are activated.

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Key words: Exercise - Energetic balance - Hormonal regulation

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Introduction

Physical exercise triggers off significant changes in the functioning of numerous systems, including the hormonal system. Behaviour of hormonal and metabolic parameters essential for the control of energetic balance depends on physical exercise intensity and duration. Between such hormons as neuropeptide Y (NPY), leptin, insulin, C-peptide and insulin clearance, growth hormone (GH), and somatomedin C (insulin-like growth factor, IGF1), as well as glycaemia, related to these parameters, different relationships can exist during exercise and restitution.

Leptin, secreted by the fat tissue, inhibits appetite, stimulates activity of the sympathetic nervous system, and enhances metabolism mainly via increase in thermogenesis – energy expense. Leptin biosynthesis was also detected in other tissues, including skeletal muscles [35]. Leptin receptors are found, beside the hypothalamus, in numerous other organs, mainly in the adrenal glands, liver, thyroid gland, gonads and skeletal muscles. Physical exercise inhibitory influence on leptin concentration can be independent of fat tissue volume changes [10,11,37].

NPY is secreted by the hypothalamic arcuate nucleus - that plays an important role in integration of signals related to the energetic balance of the organism [23,28]. NPY secretion in this nucleus is modified by insulin, leptin and catecholamines [1,29,30]. NPY stimulates food intake and inhibits activity of the hypothalamus - pituitary - thyroid axis contributing to decreased thermogenesis and to smaller energy expenses. NPY presents in the serum originates mainly from sympathetic nerve endings of blood vessels and of the heart that release it into synaptic clefts from which it penetrates into the bloodstream. NPY was shown to be released into the bloodstream in food deficiency after intense physical exercise enhancing vasoconstrictive action of noradrenaline [4,8,13,18,19,24,38].

Somatomedin C (IGF1) exerts significant anabolic action. Its decreased blood concentration or activity can contribute to the decreased rate of protein synthesis in the organism. At the same time, it increases availability of aminoacids (mainly alanine) indispensable for glucose production, and decreases energy requirements of the organism (decrease of energy expenses for protein synthesis, mitotic activity of cells). Synthesis and release of somatomedin are also strongly influenced by GH [27], insulin, nutritional status of the organism, energetic components of food, and probably iodothyronine as well. In insulin deficiency (caloric deficit periods, diabetes, physical exercise) decreased somatomedin concentration and increased concentration of GH are observed [9,14]. In muscle tissue somatomedin stimulates proliferation, and differentiation of myoblasts. Insulin enhances IGF1 synthesis mediated by GH. Increased GH release enhances IGF1 production that in turn, via

a negative feed-back mechanism, inhibits GH release. Peak IGF1 release can occur several hours after a stimulating impulse. NPY inhibits GH secretion, [36], but leptin, in physiological conditions, by inhibiting somatostatin release and stimulating GHRH (Growth hormone releasing hormone) secretion, stimulates GH [2]. Excess of growth hormone decreases leptin blood concentration [3].

During the first pass, about 50% of insulin is captured in the liver, and degraded in hepatocytes subsequently.C-peptide serum concentration is the indicator of concentration of pure insulin.It was shown that insulin is captured, and metabolised by cross striated muscles that have better blood supply during exercise which can also contribute to its lower concentration in the organism during physical work [7].

Despite the fact that changes of hormonal and metabolic parameters during exercise were described in many publications, not a lot of research concerning the behaviour of insulin clearance, and other parameters essential for energetic balance control during exercise, and restitution in adolescents have been carried out.

The aim of this study was to evaluate the behaviour and relationships between hormones, and metabolic blood parameters essential for energetic balance control during rest, exercise and restitution.

Materials and Methods

17 adolescent boys - cyclists (group I) and 11 adolescent boys - canoeists (group II) were examined. Basic characteristics of the subjects are presented in Table 1. The studies were carried out during the preparatory period (end of November - beginning of December). All subjects agreed to participate in the study, and give blood sampling for research purposes. Their parents also gave consent to the study, and the experimental procedures were approved by Committee of Research Ethics of Poznan University of Medical Sciences.

Each group of the above named was examined twice. The interval between the first, and the second examination lasted 3 days. The examinations were carried out in the morning. During the first study cyclists and canoeists were subjected exercise tests of gradually rising intensity until refusal - to assess anaerobic threshold, and maximal oxygen uptake (VO_2max). The test was performed on a Monark 814A cycloergometer. Exercise intensity was increased by increasing resistance of the flywheel of the ergometer at a constant rate of pedalling chosen individually by the subjects. Tests started at 40 or 50 W, and the load was increased every two minutes by a constant increment of 40 or 50 W, subsequently. The load was selected according to the body weight of the subject. The test was terminated when the subject reached the oxygen ceiling, manifesting itself a steady

state of oxygen consumption in spite of increasing exercise intensity. Measurement of gasometry parameters was done in an open system with a Beckman MMC (USA) analyser. Individual anaerobic threshold evaluation was performed with a non-invasive method based on alterations of minute pulmonary ventilation (V_E), ventilatory oxygen ratio equivalent (V_E/VO_2) and respiratory index (R) in relation to exercise load. Exercise load value after which a rapid non-linear increase of V_E, V_E/VO_2 and R in relation to exercise load occurred was agreed to be the threshold exercise load. Threshold value was expressed in oxygen consumption units and heart rate (HR) measured with a Polar PE-3000 (Finland) sport tester.

Table 1
Characteristics of study subjects

Evaluated parameter	Cyclists	Canoeists
Age (years)	15.4±1.5	16.1±1.6
Body weight (kg)	60.1±9.9	69.6±12.8
Body height (cm)	169.3±9.6	178.2±8.5
BMI (kg/m^2)	20.9±2.0	21.9±2.5
Tanner's Sexual Maturity Rating Scale (grade)	IV-V	IV-V
Sports experience (years)	3.4±1.9	4.0±2.4
VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	58.4±9.7	57.8±7.6
VO_2th ($mL \cdot kg^{-1} \cdot min^{-1}$)	41.1±7.5	42.4±8.8
$LA_{exercise}$ ($mmol \cdot L^{-1}$)	-	6.7±2.3

BMI - body mass index, VO_2max - maximal oxygen uptake, VO_2th - oxygen uptake at anaerobic threshold, $LA_{exercise}$ - lactate levels

Table 2
Cyclists' meal (breakfast)

Product	Amount	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)
Wheat roll	100 g	293	7.2	4.4	57.4
Vegetable butter	6 g	26.52	0	3.0	0
Chicken ham	30 g	36.9	5.46	1.68	0
Milk (1.5% fat)	250 mL	117	8.5	3.75	12.5
Total		473.42	21.16	12.83	69.9

Two hours prior to the second exercise stress test, the cyclists were given a light meal (the caloric value and energetic substrates composition of the meal are summarized in Table 2).

During the second study, the cyclists performed a 2-hour fixed intensity ergometric exercise determined by the heart rate - lower by 10 beats/min (±3) than the threshold value defined during the first test (aerobic exercise). Heart rate (HR) was recorded continuously during the entire test period to maintain the (individually determined) intensity. It required gradual decrease of intensity of the exercise through decrease of an ergometer wheel resistance.

The second exercise stress test of canoeists consisted of a 20-minutes cycle ergometer exercise under fasting conditions of fixed intensity determined during the first exercise so that the heart rate achieved at the beginning of the test was higher by 10 beats/min than the individually defined threshold value (aerobic - anaerobic exercise). Relatively short time of exercise duration enabled to perform it at the defined intensity.

All tests were performed using the same measuring equipment. The results of exercise parameters measurements are summarised in Table 1. During the entire exercise test, the subjects had at their disposal unlimited quantities of still, sugarless mineral water.

Before the exercise, directly afterwards and after one-hour restitution, blood pressure was measured, and blood was sampled to assess metabolic and hormonal parameters. Blood, drawn from the basilic vein, was centrifuged at the temperature of +4°C, and stored at a temperature of - 20°C until the hormones were evaluated with appropriate radioimmunoassays. Insulin was assesses with a CIS SCHERING (France) kit (code INSULIN - CT); GH - ORION DIAGNOSTICA, Finland (code 68554); C - peptide - CIS SCHERING, France (code C - PEPTIDE); neuropeptide Y - EURO - DIAGNOSTICA AB, Sweden (code EURIA-NPY, cat. No. RB 317); leptin - LINCO RESEARCH INC, USA, (code Cat. No. HL-81 HK); somatomedin C - BIOSOURCE, Belgium, (Cat. No. SM-C-RIA-CT KIP1589).

Glycaemia was determined with an enzymatic method-Abbott Laboratories MediSense Products, United Kingdom (LOT 95202). The lactate (LA) levels in the capillary blood were determined immediately after collection of the samples using a diagnostic cuvette kit (Dr. Lange, Cat. No. LKM 140, Germany).

To determine insulin degradation level the insulin clearance was calculated, i.e. molar C - peptide / insulin ratio. The following conversion coefficients were used:

$$\text{C-peptide ng}\cdot\text{mL}^{-1}\bullet 0.3=\text{C-peptide pmol}\cdot\text{mL}^{-1}$$

$$(\text{insulin }\mu\text{U}\cdot\text{mL}^{-1}\bullet 7.175)\bullet 1000^{-1}=\text{insulin pmol}\cdot\text{mL}^{-1}$$

Table 3
Mean concentrations of analysed hormonal and metabolic parameters

Parameter	Cyclists (I group)				Canoeists (II group)			
	Rest	Exercise	Restitution	Difference significance	Rest	Exercise	Restitution	Difference significance
NPY	78.2	106.1	78.6	S – W*	73.4	135.7	117.7	S – W*
$pmol \cdot L^{-1}$	±25.7	±27.1	±14.8	W- R*	±2.7	±50.1	±90.6	W-R n.s.
				S – R n.s.				S – R n.s.
Leptin	1.3	1.3	1.4	S – W n.s.	1.5	1.4	1.1	S – W n.s.
$\mu g \cdot L^{-1}$	±0.5	±0.5	±0.7	W- R n.s.	±0.7	±0.6	±0.6	W-R n.s.
				S – R n.s.				S – R n.s.
GH	2.0	52.7	8.8	S – W*	3.6	52.0	7.2	S – W*
$mU \cdot L^{-1}$	±1.1	±36.5	±6.7	W- R*	±2.6	±20.9	±3.5	W-R*
				S – R*				S – R*
IGF 1	524.9	493.2	462.3	S – W n.s.	490.2	484.1	472.4	S – W n.s.
$ng \cdot mL^{-1}$	±110.8	±82.5	±71.1	W- R*	±104.2	±84.1	±103.8	W-R n.s.
				S – R*				S – R n.s.
Insulin	54.0	11.2	8.5	S – W*	16.2	18.7	14.2	S – W n.s.
$\mu U \cdot mL^{-1}$	±32.1	±6.5	±2.2	W- R n.s.	±6.4	±4.5	±5.4	W-R n.s.
				S – R*				S – R n.s.
C - peptide	5.9	1.7	1.5	S – W*	2.6	3.2	2.5	S – W n.s.
$ng \cdot mL^{-1}$	±2.3	±0.9	±0.8	W- R n.s.	±1.0	±1.0	±0.8	W-R n.s.
				S – R*				S – R n.s.
Insulin								
clearance	6.1	7.1	7.5	S – W n.s.	7.5	7.9	8.7	S – W n.s.
$pmol \cdot mL^{-1}$	±2.7	±2.6	±2.8	W- R n.s.	±2.0	±2.4	±3.5	W-R n.s.
				S – R n.s.				S – R n.s.
Glucose	86.4	80.4	79.6	S – W*	91.3	99.8	84.6	S – W*
mg %	±11.4	±9.9	±7.8	W- R n.s.	±4.5	±12.2	±7.6	W-R*
				S – R*				S – R*

S - rest, W - exercise, R - restitution, * - difference significant at p?0.05, n.s. - non-significant

Statistical analyses were performed with a SPSS software package. The data that were estimated by normal distribution (leptin, C - peptide) were analyzed with one-way ANOVA statistical analyses. The data were analysed by paired *t* test. The relationship between selected variables was examined using Pearson's correlation. This approach resulted in some but not of all the data sets to be approximated using nonparametric tests (NPY, GH, IGF1, insulin, insulin clearance, glycaemia, LA, BMI). Wilcoxon's test was used to compare mean values within each group, whereas the Spearman's correlation coefficient was used to determine the strength of relationship between two dependent variables. All values are reported as mean ± SD. Statistical significance was set at p value <0.05.

Causal relationships shown with multiple regression analysis were subject to detailed analysis. This method enables us to assess influence of independent variables analysed on the tested parameter after elimination of the remaining independent variables, selecting the best model by introduction and elimination of subsequent independent variables - forward and backwards methods.

Results

Somatomedin C and GH: 2-hours exercise performed by the cyclists (group I) did not cause significant changes in somatomedin C blood concentration. However, value of IGF1 during restitution was significantly lower than at rest and directly after exercise. It was also shown that in the cyclists group leptin level directly after exercise, and during restitution depends on IGF1 concentration (Table 4). In the cyclists group multiple regression analysis did not confirm positive linear correlation between insulin and IGF1 ($r=0.662$, $p\leq0.05$). Despite the lack of significant differences between IGF1, and insulin concentrations in the canoeists directly after exercise and during restitution, it is worth to notice that positive relationship between these parameters directly after exercise is observed.

In both groups, value of GH directly after exercise was significantly higher than at rest.

Leptin: In these studies, differences between leptin concentration during third measurements were not statistically significant in both groups. Influence of elevated GH concentrations on leptin level decrease described elsewhere, [3], was not shown in our studies. A positive correlation between insulin and leptin found in the cyclists directly after exercise ($r=0.559$, $p<0.05$), was not confirmed in multiple regression analysis. Statistically significant positive causal relationship between leptin and insulin in the cyclists and canoeists had been found before exercise was undertaken (Table 4).

Table 4
Multiple regression analysis results

	Dependent variable	Independent variable	R^2	Significance level	Correlations
Cyclists	C - peptide (W)	Glucose	0.412	p≤0.01	0.541
	C - peptide (R)	GH	0.286	p≤0.05	-0.531
	Insulin (s)	Leptin	0.264	p≤0.05	0.529
	Insulin (w)	Glucose	0.453	p≤0.01	0.564
	Insulin clearance (R)	GH	0.275	p≤0.05	-0.462
	Leptin (s)	Insulin	0.264	p≤0.05	0.529
	Leptin (w)	IGF1	0.380	p≤0.01	0.707
	Leptin (R)	IGF1	0.290	p≤0.05	0.548
	Systolic RR (w)	NPY	0.404	p≤0.01	0.718
	Diastolic RR (w)	Leptin	0.381	p≤0.01	0.604
	Diastolic RR (R)	Leptin	0.411	p≤0.01	0.615
	IGF1(w)	Leptin	0.380	p≤0.01	0.707
	IGF1(R)	Leptin	0.290	p≤0.05	0.548
Canoeists	C - peptide (s)	Leptin	0.781	p≤0.001	0.884
	C - peptide (w)	Glucose	0.574	p≤0.01	0.764
	Insulin (s)	Leptin	0.457	p≤0.05	0.599
	Insulin (w)	IGF1	0.853	p≤0.01	0.641
	Insulin clearance (R)	LA	0.615	p≤0.01	0.719
	Leptin (s)	Insulin	0.457	p≤0.05	0.599
	NPY (w)	LA	0.458	p≤0.05	0.742
	IGF1 (w)	Insulin	0.426	p≤0.05	0.641

RR - blood pressure, R^2 - model fitting (the closer to 1 the value is, the better the multiple regression model is fitted), p - shows at what level the influence of an independent variable on a dependent variable is significant, S - rest, W - exercise, R - restitution,

*Insulin, C-peptide, glycaemia:*In the group of cyclists, value of C-peptide and insulin directly after exercise was significantly lower than value of these parameters at rest. Such diferences had not been found in the canoeists group.

In group I glycaemia was significantly lower directly after exercise than at rest, but in group II it was significantly higher. Multiple regression analysis has shown that in the cyclists group insulinemia as well as C-peptidaemia depend on glucose level, and in the canoeists only C-peptidaemia.

Table 5
Linear correlations during exercise and restitution (statistically significant at $p \leq 0.05$), not confirmed by multiple regression analysis

	Parameters	Exercise	Restitution
Cyclists	Insulin - Leptin	0.559	n.s.
	IGF1 - Insulin	0.662	n.s.
	Insulin - GH	-0.457	n.s.
	C - peptide - Leptin	0.49	n.s.
	C - peptide - GH	-0.599	n.s.
	C - peptide - IGF1	0.624	n.s.
	Leptin - GH	-0.496	n.s.
	GH - Glucose	n.s.	-0.529
	Insulin clearance - IGF1	n.s.	0.608
	Systolic RR - Insulin	0.514	n.s.
	Diastolic RR - NPY	0.546	n.s.
	Diastolic RR – Insulin	0.514	n.s.
Canoeists	LA - Glucose	0.799	n.s.
	LA - C - peptide	0.769	0.59
	Insulin - Glucose	n.s.	0.61
	C - peptide - Leptin	n.s.	0.61
	C - peptide - IGF1	n.s.	0.558
	Leptin - Glucose	0.638	n.s.
	Insulin clearance - NPY	0.698	n.s.
	Insulin clearance - Glucose	0.683	n.s.
	Systolic RR - Leptin	0.581	n.s.

RR - blood pressure, n.s - non-significant

Insulin clearance: Differences between values of insulin clearance measured at rest, directly after exercise, and during restitution were not statistically significant

in both groups. This fact can indirectly show that muscles participation in insulin capture increases while simultaneous insulin degradation in the liver decreases. Nevertheless, in the cyclists group influence of GH and in the canoeists group influence of LA on insulin clearance one-hour after exercise was found.

NPY: In both groups, the NPY concentration was significantly higher directly after exercise than at rest. However, only in group I its value was significantly lower during restitution.

*Lactic acid(LA):*Lactate concentration level in the canoeists group after 20-min effort (6.7±2.27 mmol·L^{-1})confirms that contribution of anaerobic processes during exercise was significant (Table 1).

Blood pressure: Testing, with multiple regression analysis, the influence of analysed hormonal parameters on blood pressure evolution, NPY influence on increase of systolic blood pressure directly after exercise, and leptin influence on diastolic blood pressure values directly after exercise, and restitution was shown in group I. No similar causal relationships were observed in group II.

Discussion

At rest, all hormonal and metabolic parameters analysed are within the normal limit range in both study groups. Higher insulin and C-peptide concentrations in group I resulted from the meal taken 2 hours before.

As it has been already mentioned, somatomedin C (IGF1) exerts anabolic action. Decrease of its concentration in blood slows down protein synthesis, enhances availability of aminoacids necessary for glucose production, and reduces energy expense for protein synthesis. Thus, the decrease of somatomedin concentration observed by us in group I (cyclists) can play a significant role. It is consistent with the observation, [5], that prolonged physical exercise does not significantly exert influence on muscle mass enlargement (muscle anabolism depends strongly on IGF1). Lower level somatomedin C, and insulin (anabolic action), and increase of GH concentration favour the maintenance of appropriate glucose level in the central nervous system during prolonged exercise.

In group II, in contrast to group I, the values of the IGF1during third measurements did not differ significantly. We noted, however, a positive relationship between somatomedin C and insulin directly after exercise (Table 4). Furthermore, after 20-min exercise (in group II) influence of LA on the NPY level rise was found. Demonstrated in these studies, influence of lactic acid on insulin clearance increase one hour after exercise, suggesting enhanced insulin use in anabolic processes in that period, seems to be significant as well. We conclude

therefore that after 20-min exercise conducted above anaerobic threshold some immediate mechanisms occur (noticeable shortly after exercise) favouring restitution processes, which is desirable and justified by the organism's post-exercise demand for enhancement of metabolic processes leading to protein synthesis, and activation of mitotic capacity of muscle cells. At the same time, it explains the universally observed tendency for larger muscle volume growth in subjects performing short anaerobic exercises [5,12,26]. In these circumstances, up-regulation of anabolic processes can also be caused by potentially larger muscle injury occurring at intense exercise and higher (in this situation) demand on anabolic processes. These processes are regulated by many hormonal mechanisms discussed above, as well as by other mechanisms (e.g. local mechanisms, related to muscle cells injury). At the same time, when interpreting these relationships, the fact that higher GH levels occurring directly after exercise in both groups can cause IGF1 rise only after a few hours (when GH level already decreased), favouring this way restoration processes in the organism, should be taken into consideration.

In these studies no close relationships between GH and somatomedin C were found in both groups. Significant rise of GH concentration directly after exercise is not related with significant somatomedin concentration rise, however, we do not exclude that a post-exercise period (1 hour) was too short to demonstrate any relationship with exercise. On the other hand, significant GH rise between rest, and the exercise period observed in both groups, is justified by GH participation in mobilisation of energetic substrates during exercise - FFA, activation of glycogenolysis and gluconeogenesis. This action can thus be important not only during prolonged exercise (as other authors suggest), [6,17,31,32,33,34], but also during short exercises (intense, anaerobic).

Value of insulin clearance (interpreted as a sum of muscle and liver clearance) did not change significantly in our studies, which means that role of higher insulin capture, and degradation in the liver, and in skeletal muscles in the process of insulin concentration decrease was not confirmed in these studies. Some other mechanisms are also involved in insulin secretion suppression during prolonged aerobic muscle work, e.g. inhibitory action of catecholamines.

The decrease of glycaemia directly after exercise in cyclists is accompanied by the decrease of insulin and C-peptide level (positive correlation confirmed with multiple regression analysis). We also do not exclude postprandial insulin, and glucose concentration decrease in response to their increase after food stimulus. However, it seems to be of lesser importance in relation to the relatively long (two hours) period preceding the exercise. The decrease of insulin blood concentration directly after exercise is a desirable phenomenon as it assures better glucose supply

(increased glucose level secondary to diminished suppression of glycogenolysis and gluconeogenesis by insulin) for exercised muscles participating in the aerobic process of energy production. Moreover, the decrease of insulin blood concentration results in reduced glucose consumption in some tissues (fatty tissue, resting muscles) saving it up for the brain and working muscles. Glucose capture by working muscles is less dependent on insulin concentration but it is rather related to local factors, among others to increased number of glucotransporters (GLUT4) during exercise [15,16].

Increase of blood glucose concentration in canoeists directly after exercise revealed in these studies, shows efficiency of regulatory mechanisms (catecholamines, glucagon, glucocorticosteroids, GH). Increased glycaemia can cause the lack of decreased insulin secretion by the pancreas during exercise (positive relationship between glycaemia and C-peptidaemia was noticed).

In our studies decrease in leptin concentration directly after exercise was not found, which can also be a result of increased NPY level. Physical exercise, and its related energetic substrate deficit did not reveal their effect on the decrease of leptin concentration as at the same time increased NPY level stimulating increased leptin levels can lead to maintenance of its constant blood level (however multiple regression analysis failed to show such a relationship). Drop of insulin concentration directly after effort in group I did not cause concurrent diminishing of leptin levels in that period, either. Positive correlation between insulin and leptin was found at rest in both groups. Positive correlation between somatomedin and leptin was demonstrated in the cyclists group, one hour after exercise, which (with observed decreased somatomedin levels) did not result in decreased leptin level.

Other authors' results suggest, [8,18,24], increase of NPY concentration during physical exercise. In our studies we also obtained significant rise of NPY in group I and II, observing a drop of concentration of this peptide in restitution in cyclists only. At the same time, we observed reduced insulin concentration following exercise in group I. We did not demonstrate correlation between NPY and insulin in any of studied groups. NPY inhibits sympathetic activity of the nervous system, thereby diminishing energetic expense. Anabolic action of higher NPY concentrations after exercise can be a factor counterbalancing concurrent catabolic effect of catecholamines and glucagon (among others) as well as decreased insulin and IGF1 levels during prolonged exercise (group I - cyclists).

Demonstrated in these studies, negative correlation during restitution in group I between GH and C-peptide, and insulin clearance at lower growth hormone concentration can favour anabolic processes, and organism restoration during restitution period through increased pancreatic insulin secretion (C-peptide rise)

and its increased tissue consumption (increase of insulin clearance).

Influence of insulin on blood pressure secondary to renal sodium retention, and increased adrenergic system tone described elsewhere, [25], was reflected in cyclists directly after exercise by significant positive linear correlation between systolic and diastolic pressure and insulin. However, this relationship was not demonstrated with multiple regression analysis. Causal relationship between blood pressure and NPY directly after exercise, demonstrated in cyclists can point to potentialising influence of NPY on vasoconstrictive noradrenaline activity, described elsewhere [20,21,22]. Influence of leptin on blood pressure rise, revealed at the same time, can suggest its participation in increase of the sympathetic nervous system activity.

Conclusions

Physical exercise alters hormonal balance of the organism. These alterations involve many hormonal and metabolic parameters and their extent, and duration depend, among other things, on the intensity and duration of the exercise. The direction of occurring metabolic alterations favours, first of all, a supply of necessary energetic substrate (glucose) for central nervous system during exercise. At the same time, some mechanisms facilitating organism restoration during post-exercise restitution periods are noticeable. Restoration mechanisms are activated earlier after intense 20-min exercise performed above anaerobic threshold. The ability to quickly regenerate the energy resources of the organism, to restore muscle structures and to stabilise homeostasis at the resting level after exhaustive exercise can be an important indicator of high sports performance**.**

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