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ASSOCIATION OF THE PHYSICAL ACTIVITY WITH LEPTIN BLOOD SERUM LEVEL, BODY MASS INDICES AND OBESITY IN SCHOOLGIRLS

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Decreased physical activity is undoubtedly significantly associated with obesity. Similarly, the proper hormones secretion, the proper weight and body development. The aim of this study was to investigate the relationship between body mass composition and leptin concentration in relation to the degree of physical activity expressed in MET-h/week (metabolic equivalent per week). The study included 59 girls, aged 9-16 years (12.55±1.67) and divided into two groups: 1) PA: a physically active group of 29 girls and 2) PI: a group of 30 physically inactive girls. In all, physical activity was assessed using modified questionnaire concerning "activity for adolescents" and expressed in MET-h/week. Serum blood leptin concentrations in fasting girls were determined by RIA. Anthropometric parameters were measured and fatness indices calculated (BMI, SF, WHtR). Body composition (%BF, FM, FFM) was assessed using bioelectrical impedance analysis method (BIA). Statistical analysis showed significant differences between groups of PA and PI concerning values of BMI, WHtR, %BF, WC and MET-h/week as well as in leptin concentrations. In both groups of girls negative correlations between physical activity measured in MET and leptin concentrations and in WHtR were observed. The concentration of leptin was directly proportional to the degree of body fat and to the body composition expressed by BMI, WHtR, log SF, WC and %BF, FM and FFM, respectively. Increased physical activity was associated with lower body fat ratios and WHtR, BMI, WC, %BF, but did not affect significantly the changes in the values of log SF, FM and FFM. Higher values of BMI, WHtR and WC can provide not only a greater risk of obesity in general, but also cause excessive accumulation of fat in the central part of the body (abdominal obesity).

Key words: *leptin, body weight, obesity, adolescent girls, physical activity, body mass index, exercise*

INTRODUCTION

An increase of overweight and obesity in children and teenagers observed for the last years has become an important health problem (1). The main factors thought to be responsible for the situation are excessive food consumption, lack of physical activity, genetic determinants connected with parents' overweight and low socio-economic status of the family (2, 3). Soric *et al.* (4) found lower level of moderate and intensive physical activity in obese 11-year-olds in comparison to their non-obese peers. Additionally, it was observed that lack of physical activity, disregarding body mass, increases the risk of metabolic and cardiovascular diseases prevalence (5). Therefore, maintaining proper level of physical activity is so important in preventing and treating obesity (6, 7). It was also shown that gestational weight gain may be a risk factor for overweight in early childhood (8).

For many years scientists have been investigating the way brain receives information on the level of the organism energy sources influencing the control of the appetite process. Coleman and Hummel (9) describing an experiment with parabiotic mice found that there was an agent in blood linking the organism and brain and participating in obesity control. In 1994 Zhang *et al.* (10) discovered the obesity gene *ob* and protein coded by the gene called leptin (from a Greek word „leptos" meaning slim). The discovery significantly increased interdisciplinary interest in endocrinology and the influence of adipose tissue on maintaining energy balance of the organism (11).

The influence of leptin on obesity

The studies of Considine *et al.* (12) and Hassink *et al.* (13) proved that the level of leptin in blood serum is higher in the obese in comparison with both adults and children of proper body mass. Proportionality of leptin level to adipose tissue mass suggests occurrence of the state of 'leptin resistance' at the level of hypothalamus in obese people. It may result in increased appetite and lowered energy expenditure despite correct leptin production by fat cells (14-17). In such cases high level of leptin does not provide expected biological effects. The phenomenon is clarified as an attempt of brain to 'protect itself' against possible consequences of hyperleptynemia *i.e.* body mass fall, pubescence disorders, height anomalies by blocking leptin penetration thorough the blood-brain barrier (18). According to the latest studies, a high level of serum leptin in children may indicate a high risk of obesity in adults (19, 20). Sinha *et al.* (21) claim that leptin released from adipocytes may bond some blood proteins. In slim people the majority of total leptin (60-98%) occurs in the circulation of blood in such a form, whereas in obese people most of the circulating leptin is in a free form. Considering mass of body and adipose tissue, the level of leptin is higher in girls than in boys (13, 22). The sex differentiation results from a few factors. First, the amplitude of leptin secretion from adipose tissue is two or three times higher in girls than in boys (23). Second, girls have higher mass of adipose tissue and it is distributed in a different way than in boys (24) and finally girls have higher total level of leptin and lower level of protein that bonds leptin which indicates an increased level of free leptin level (25).

Leptin versus physical activity

It is well known that physical exercises effectively reduce adipose tissue mass and also lower the level of leptin in blood serum (26). Due to the fact that leptin is connected with pubescence, the changes in its level induced by physical training could explain the mechanism of intensive physical exercises influence on maturation retardation found in tests including female athletes (26-31). Physical exercises also influence concentration of other hormones such as: insulin, cortisol, catecholamine, estrogen, testosterone, dehydroepiandrosterone (DHEA) and growth hormone which can affect the change of leptin concentration, too (26). Several tests on correlation of leptin and physical activity indicate many ambiguities and do not provide clear results (11). The influence of short-term exercises (<60 min) on leptin level in serum showed a fall or lack of changes in leptin concentration regardless of exercises intensity, both in healthy males and females. Also, in case of long-term exercises (>60 min) not all tests results demonstrated changes in leptin level (26). Hilton and Loucks' s studies (32) found that exercises did not influence leptin circadian rhythm, but only affected disorders of energy balance in young females. In some parts of the tests (>12 weeks) the influence of exercises on leptin concentration was not found, apart from the one caused by body mass decrease (26). However, it should be emphasized that some latest studies suggest occurrence of leptin level changes delayed by a few hours (from 2 to 48), but physiological importance of the delayed leptin decrease is unclear (33-36). Analysing the above presented results, one can feel frustrated trying to find clear dependency between blood serum leptin concentration and physical exercise (11).

The aim of the work was to assess correlation of physical activity and blood serum leptin concentration in connection to body mass composition and selected indices of the examined girls` fatness.

MATERIAL AND METHODS

The tests included 59 girls aged 9-16 years (12.55±1.67) attending two primary and secondary schools. Girls from the Sport Championship School (n=29) who did regular swimming training on average 6.93±4.98 month/year, 5±1.86 days/week and 2.20±1.07 hours/day were categorized to the PA group (physically active). The examined attending a regular school (n=30) who were physically active on average for 6.94±4.15 month/year, 1.69±1.09 days/week and 1.11±0.46 hours/day were categorized to the PI group (physically inactive). In both schools physical activity was assessed by the number of METs (metabolic equivalent) in relation to physical activity besides physical trainihg classes. Children's parents' or guardians' approvals as well as a permission from the Bioethical Commission were obtained to conduct the research.

Anthropometric measurements

Measurements of body height and mass were made to the nearest 0.1 cm and 0.05 kg, respectively, in order to implement the aims of the work. The examined girls were wearing light sports clothes without shoes. The measurements took place in the morning. The BMI was calculated, as well as the logarithm of the sum of three skinfold (log SF) thicknesses: abdominal, subscapular and triceps. Waist circumference (WC) measured in the middle between the lower edge of costal arch and the upper edge of iliac crest, and the relation of waist circumference to height (WHtR) were applied as indices of adipose tissue distribution. The body composition analyzer TBF 300 was used to calculate the percentage of body fat mass (%BF), fat mass (FM) and fat free body mass (FFM) applying the method of bioelectrical impedance analysis (BIA).

Assessment of physical activity

The assessment of physical activity in the examined girls was performed with the use of the Modified Activity Questionnaire For Adolescents (37). The measure of energy consumption during training MET (metabolic equivalent) was used to evaluate the level of motor activity in the girls. The MET number for a given kind of physical effort shows how much more energy we consume performing the activity than if we rested at the same time. Each form of activity received a certain number of METs and the measure of physical activity was the sum of METs obtained from particular sport disciplines. Total assessment of activity was calculated based of the MET formula expressed as MET-h/wk.

Biochemical (hormonal) determinations

Blood samples were collected after overnight fast, between 8 and 9 a.m. The concentration of leptin in blood serum was determined at Isotope Laboratory (Department of Physiology, Jagiellonian University Medical College, Krakow) using radioimmunoassay method for human leptin (h-Leptin RIA. kit, cat #HL-81K, Millipore, Missouri, USA)

Statistical analyses

In the description of the examined groups the measure of central tendency was expressed as arithmetic mean with its standard error (S.E.), while the measure of dispersion was presented as standard deviation (S.D.).

Due to data distribution significantly different from the normality comparison of the examined quantitative parameters values between the two groups of girls the non-parametric Wilcoxon test was applied.

Whereas, for examination of mutual dependencies between qualitative parameters the Pearson linear regression was used. The values of calculated statistics (R^2 and F) and the level of their significance were presented at description and interpretation of the obtained results. According to criteria common in biological sciences, the boundary of statistical significance was accepted at $p=0.05$.

The tests were a part of the project 'Concentration of Ghrelin, Leptin and Growth Hormone (GH) in Prepubertal Girls *vs*. Distribution of Adipose Tissue in the Aspect of Differentiated Physical Activity (longitudinal studies)' (project No. 214/KF/2006l; Suder and Plonka).

RESULTS

The level of physical activity was significantly different in the PA and PI groups of girls. It mainly resulted from different profiles of their schools *e.g.* a better access to the swimming pool for PA girls.

Intensity of swimming training in PA and PI girls was compared with the use of the Wilcoxon test. The difference in the number of months of practising swimming between the examined groups was close to statistical significance (Z=1.793; p=0.0715) (*Fig. 1*). The same comparisons performed for number of days per week and the training duration indicated that PA girls swam significantly more frequently (Z=3.633; p=0.0003) and longer (Z=3.114; p=0.0018) (*Fig. 2* and *3*).

Basic statistical characteristics of the selected parameters in the examined girls divided onto physically active (PA) and inactive (PI) groups were presented in *Table 1*. Most of the anthropometric parameters differed significantly between the compared groups. The highest differences concerned the level of leptin, WHtR index and the MET-h/wk number.

For clearer presentation of differences in the examined anthropometric and physiological parameters depending on the level of physical activity, the girls were divided into three groups

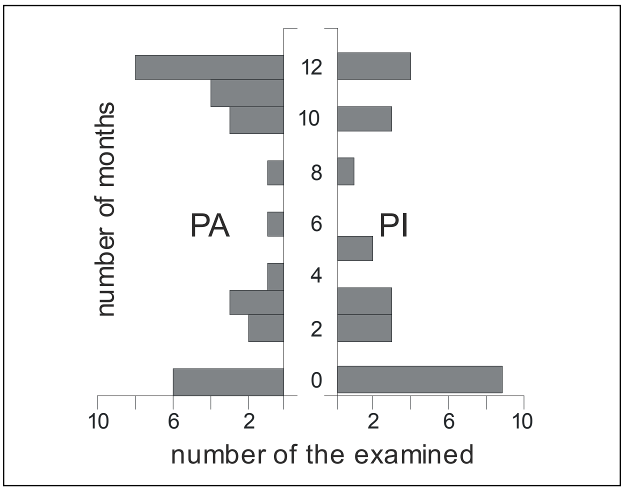

Fig. 1. Monthly intensity of swimming training in PA and PI groups.

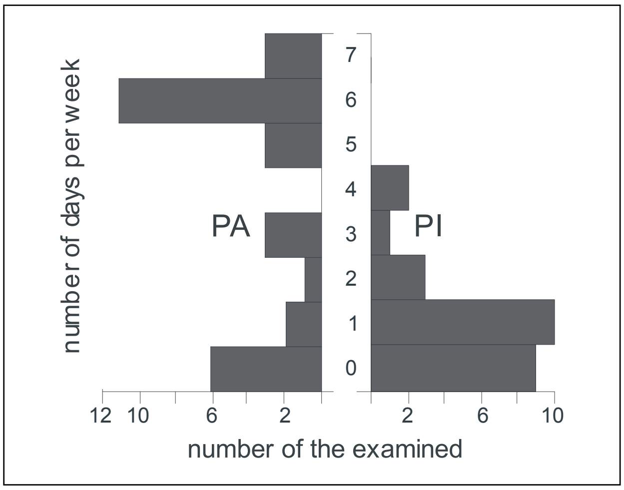

Fig. 2. Weekly intensity of swimming training in PA and PI groups.

Table 1. Characteristics of the examined girls divided into PA and PI groups.
* indicates statistically significant difference at p<0.05 in values of individual parameters in girls from PA group in comparison with the ones from PI group.

Parameters	**PA** (n = 29) Mean	SD; SE	**PI** (n = 30) Mean	SD; SE	t	p
BMI	18.19	2.29; 0.43	20.57	4.33; 0.80	-2.62	0.0122*
WHtR	0.41	0.02; 0.00	0.49	0.06; 0.01	-6.92	<0.00001*
BF [%]	18.39	7.02; 1.30	22.97	9.72; 0.80	-2.05	0.0451*
FM [kg]	9.22	4.97; 0.92	12.34	7.62; 1.42	-1.85	0.0710
FFM [kg]	37.86	5.60; 1.04	36.10	7.43; 1.38	1.02	0.3146
WC [mm]	652.59	48.12; 8.94	748.28	118.69; 22.04	-4.02	0.0003*
Log SF	1.47	0.17; 0.03	1.55	0.23; 0.04	-1.47	0.1467
MET [h/wk]	99.96	65.11; 12.09	36.95	26.40; 4.82	8.41	<0.00001*
LEPTIN [ng/ml]	**3.61**	2.33; 0.43	**12.34**	7.33; 1.34	-6.21	<0.00001*

of physical activity based on characteristics of METs values distribution:
1. Low physical activity (I quartile of MET values).
2. Moderate physical activity (II and III quartile of MET values).
3. High physical activity (IV quartile of MET values).

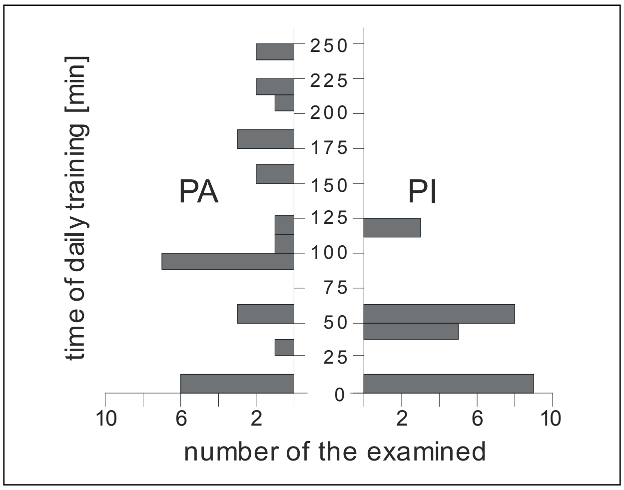

Fig. 3. Daily intensity of swimming training in PA and PI groups.

Table 2 presents parameters of METs distribution in the whole examined sample also divided into physically active (PA) and inactive (PI) groups. A significant difference in METs distribution parameters between the examined groups of girls was shown.

Table 3 presents characteristics of the size of physically active (PA) and inactive (PI) groups and all examined girls in relation to their belonging to particular quartiles expressing a certain level of physical activity.

On the basis of that division it can be stated that the PA group is characterized by high (quartile IV) and moderate (quartile II and III) physical activity, whereas the PI group by low (quartile I) and moderate (quartile II and III) one.

Table 4 shows mean values, S.D. and S.E. of leptin level in blood serum expressed in ng/ml and values of WHtR index in all examined girls with division into physical activity quartiles.

Fig. 4 presents a diagram of leptin level in blood serum in all examined girls with division into physical activity quartiles. The number of girls from particular quartiles and mean values of S.D. and S.E. are to be found in *Tables 3* and *4*.

There was observed a statistically significant higher level of leptin in the examined girls from quartile I - of low physical activity, whereas lower level was noticed in girls from quartile

Table 2. Summary distribution of the number of METs in all examined girls and with division into PA and PI groups.

	PA (n=29) [MET-h/wk]	**PI (n=30)** [MET-h/wk]	**TOTAL (n=59)** [MET-h/wk]
Mean	**99.96**	**36.95**	67.92
S.D.	65.11	26.4	58.33
S.E.	12.09	4.82	7.59
quartile I	45.42	**14.36**	27.16
quartile IV	**146.78**	58.27	90.30

Table 3. Characteristics of the quantity of physically active groups of girls (AS) and inactive ones (PI) divided into 3 types of physical activity.

Examined groups	**quartile I** low physical activity	**quartile II and III** moderate physical activity	**quartile IV** high physical activity	**Total** N=59
PA	2	14	13	29
PI	12	17	1	30

Table 4. Leptin concentration in blood serum in ng/ml and values of WHtR in the examined girls divided into physical activity quartiles expressed in METs.
* indicates statistically significant difference at $p<0.05$ in leptin level and WHtR index in the examined girls in particular quartiles of physical activity.

Leptin [ng/ml]	**quartile I** low physical activity	**quartile II and III** moderate physical activity	**quartile IV** high physical activity	**Significance level**
Mean	**11.99**	7.97	**4.27**	
S.D.	8.80	6.55	3.09	p=0.0115*
S.E.	2.35	1.18	0.82	
WHtR				
Mean	**0.49**	0.44	**0.42**	
S.D.	0.07	0.06	0.02	p=0.0020*
S.E.	0.02	0.01	0.00	

IV - of high physical activity. The results confirm a noticeable correlation between physical activity and the level of leptin in blood serum.

Fig. 5 shows a diagram illustrating WHtR index values in relation to the level of physical activity divided into quartiles and expressed in METs.

The examined girls from quartile I - of low physical activity, were characterized by the highest values of abdominal fatness index WHtR. On the contrary, the lowest WHtR values were obtained by girls qualified to quartile IV - of highest physical activity. The number of the examined girls from particular quartiles and mean values of S.D. and S.E. got presented in *Tables 3* and *4*. The obtained results of leptin and WHtR index levels were shown in the form of Pearson linear regression with the sum of METs.

Fig. 6 includes a diagram of correlations between density of leptin in blood serum and the level of physical activity expressed in METs in the whole group of the girls. The regression is expressed by the equation:

$$y=21,380269 - 3,4262012*\log(x)$$

where y responds to leptin in ng/ml, whereas x to the sum of METs values.

A negative relation between the level of physical activity measured in METs and the concentration of leptin in blood serum was found for the whole examined group of girls ($R^2=0,2094$, $F=13,1855$, $p<0,0001$). An increase of the number of METs was accompanied by a decrease of leptin level in blood serum in the examined girls.

Fig. 7 presents a diagram of correlation between WHtR and the level of physical activity expressed in METs in the whole examined group. The regression was described with the equation:

$$y=0,5843437 - 0,0348992*\log(x)$$

where y responds to WHtR, whereas x to the sum of METs values.

A negative relation was also observed for the whole group between WHtR and the level of physical activity measured in METs ($R^2=0,2466$, $F=18,0114$, $p<0,0001$). A low number of METs, and consequently a low physical activity, indicated a high abdominal fatness index of WHtR.

Table 5 shows values of Pearson linear regression coefficients (R^2), values of F statistics and significance levels (p) between the level of leptin and the tested variables divided into physically active (PA) and inactive (PI) groups.

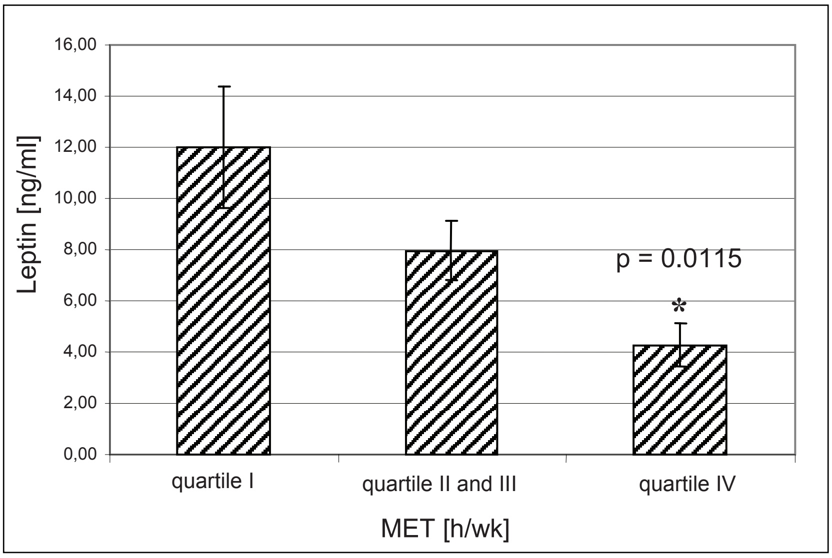

Fig. 4. Leptin levels in blood serum divided into quartiles of physical activity expressed in MET-h/wk.
* indicates statistically significant difference in leptin level at p<0.05 in the examined girls in various quartiles of physical activity.

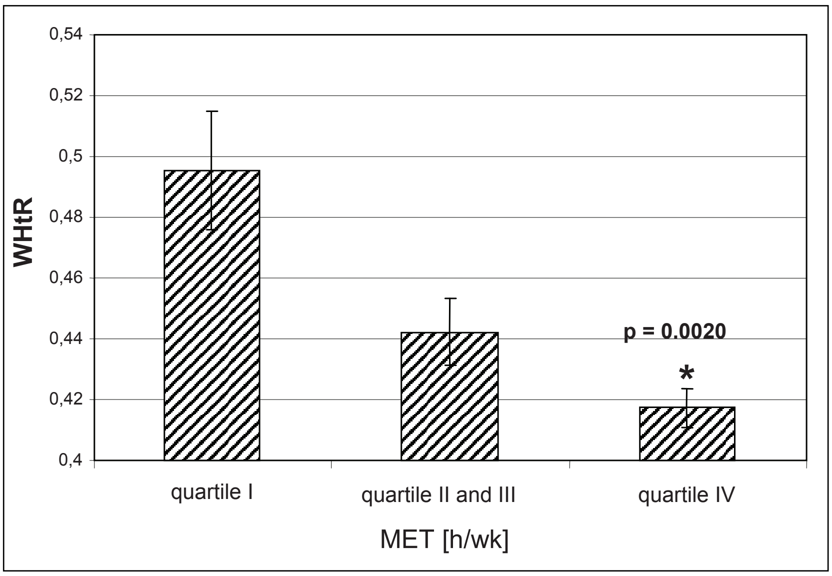

Fig. 5. WHtR index values divided into quartiles of physical activity expressed in MET-h/wk.
* indicates statistically significant difference in WHtR value at p<0.05 in the examined girls in various quartiles of physical activity.

The obtained results indicate statistically significant correlations between leptin concentration in blood serum and elements of body composition, *i.e.* %BF, FM, FFM as well as BMI and WHtR indices (*Table 5*). A significant relation was also found between leptin concentration and log SF and WC.

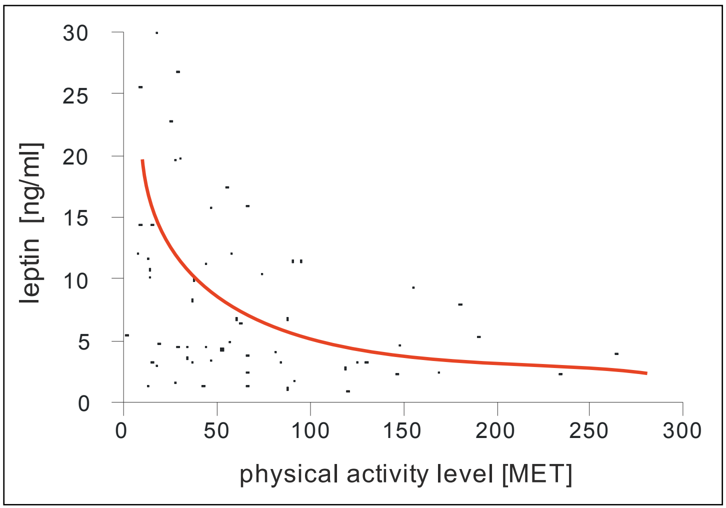

Fig. 6. Relation between leptin and physical activity expressed in METs in the whole examined groups of girls.

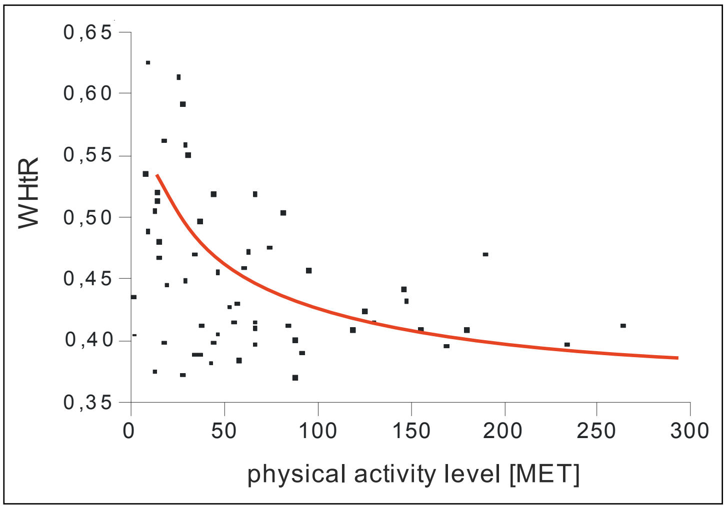

Fig. 7. Relation between WHtR and physical activity expressed in METs in the whole examined groups of girls.

Table 5. The Pearson linear regression coefficients (R^2), coefficient F and significance levels (p) between leptin level and examined variables divided into physically active group (PA) and inactive one (PI).
* indicates statistically significant relation at $p<0.05$ of the examined parameters and leptin level in girls from PA and PI groups.

Parameters	**PA**	**PI**
BMI [kg/m^2]	R^2=0.607; F=41.749; p<0.0001*	R^2=0.787; F=99.961; p<0.0001*
WHTR	R^2=0.139; F=4.390; p=0.0456*	R^2=0.468; F=23.791; p=0.0034*
BF[%]	R^2=0.599; F=40.419; p<0.0001*	R^2=0.657; F=51.750; p<0.0001*
FM [kg]	R^2=0.667; F=54.146; p 0.0001*	R^2=0.736; F=75.447; p<0.0001*
FFM [kg]	R^2=0.334; F=13.572; p=0.0010*	R^2=0.502; F=27.231; p<0.0001*
WC [mm]	R^2=0.391; F=17.353; p=0.0003*	R^2=0.565; F=35.197; p<0.0001*
Log SF	R^2=0.509; F=28.094; p<0.0001*	R^2=0.626; F=45.283; p<0.0001*

DISCUSSION

Relations between physical activity and control of leptin secretion are still an interesting subject due to the fact that researches being conducted in the field do not provide unequivocal results. For instance, Racette *et al.* (38) did not find changes in leptin concentration in blood serum measuring it during a cyclic, 60-minute-long exercise on an ergometer. Also, in studies of Dirlewanger *et al.* (39) no changes were observed in the level of the determined hormone after 3 days of a moderate cycling training of intensity at 60% VO_2 max lasting 30 min. On the other hand, Essig *et al.* (34) reported a 30% decrease of leptin concentration after 48 h since the finishing of exercises requiring 1500 kcal energy expenditure. However, they did not observe differences in leptin level after an exercise requiring 800 kcal, regardless of the measurement time. A similar, 30% reduction of leptin was found in 8 athletes after an intensive 2-hour run already in the 2nd hour of rest (33). Tuominem *et al.* (36) also observed a 34% fall in leptin concentration after 24 h since the end of a 2-hour exercise on a running track at 75% VO_2 max. The authors of the study declared correlation of leptin with factors controlling the organism energy homeostasis. Olive and Miller (40) presented 18% decrease of leptin after 24 h and 40% after 48 h caused by a 60 min run at 70% VO_2 max and the use of 900 kcal but they did not achieve a decrease of leptin after a short-term endurance exercise consuming 200 kcal.

The tests results analysing the influence of long-term exercises are also divergent. Houmard *et al.* (41) tested an influence of aerobic exercises (1 h daily at 75% VO_2) on leptin concentration in healthy young and older males and observed that the training did not affect the level of the hormone. Kraemer *et al.* (42) did not find changes in leptin level in obese women after 9-week-long aerobics, either. The examined females did not follow any diets and did not undertake any other exercises during the tests. Despite a better physical fitness, the increased energy expenditure accompanied by no reduction of energy delivered with nutrition neither influenced significantly the changes in adipose tissue and BMI, nor was it a sufficient stimulus to induce changes in leptin level. Perusse *et al.* (43) were observing leptin reaction in obese females and males to intensive, single exercises practised 3 times a week for 20 weeks. The level of leptin did not change significantly, neither during the exercises, nor during the rest, despite a decrease of FM.

The assumption of the work was to demonstrate that in girls from the PA group *i.e.* with higher number of METs, the level of leptin in blood serum was lower than in girls from the PI group. Whereas, calculated indices of fatness, namely BMI and WHtR allowed more precise determination of the quantity and distribution of adipose tissue in the examined girls.

On the basis of the obtained results it was found that the PA girls were thinner than the PI ones. Mean value of %BF in the active group was significantly lower than in the inactive one. Whereas, no significant differences were observed between the groups in the values of log SF, FM and FFM. Although, FM in the PA group was lower than in PI, the lack of significance resulted from high dispersion of the obtained values. It was probably caused by the fact that highly obese people of small total body mass could have FM close to the one in low obese people of high total body mass. In such a case %BF was accepted as a reliable measure of fatness, as it presents fat content in relation to the total body mass. Similarly, Riddoch *et al.* (7) indicated that higher level of physical activity was connected with lower value of FM. An increase of intensive physical activity by 15 minutes daily for 2 years at the age of 12 caused a decrease of FM at the age of 14 by 10% in girls and 12% in boys. At the same time the authors of the work indicated that intensive physical exercises can lead to an increase of muscle tissue mass, and consequently the value of FFM.

In order to demonstrate correlation of concentration of leptin determined in blood serum and physical activity, the examined girls were divided into 3 levels of physical activity measured in METs, according to quartiles: I quartile - of low physical activity, II and III quartiles - of moderate physical activity, IV quartile - of high physical activity. The division showed that leptin concentration depends on the level of physical activity. The lowest level of the hormone was measured at high physical activity, a higher one at moderate activity and the highest one at low physical activity. The result is in accordance with the accepted assumption that leptin level in blood serum is in inverse proportion to the level of physical activity.

The obtained results are confirmed in researches of different teams of scientists. Landt *et al.* (44) indicated a 32% decrease in leptin level after run on a distance of 101 miles (ultra marathon) within 35 hours, determining leptin concentration in the runners before and after the exercise test. Similar results were obtained by Leal-Cerro *et al.* (35) examining 29 athletes after running a marathon and observing reduction of adipose tissue in their bodies at the same time. Hickey *et al.* (45) also obtained after 12-week-long aerobic training a significant decrease in leptin level in young females (mean age 29 years), but not in young males (mean age 27 years). A fall of leptin in women appeared without significant changes in adipose tissue mass. The result suggests a higher influence of training on leptin level on female organisms than on male ones. Okazaki *et al.* (46) examined an influence of 12-week-long moderate aerobic exercises (50% VO_2 max) as well as application of individual diets on a decrease of fat mass and leptin concentration in obese and non-obese women at average age leading a sedentary lifestyle. The authors obtained lower leptin concentration, regardless of changes in adipose tissue mass. In a test including 24 obese girls and 10 obese boys a decrease of fat mass and leptin concentration was observed after four months of trainings (exercises on sporting instruments and sports games) then, after a four-month period without physical exercises the level of fat mass and leptin increased again. Also, a higher reduction of leptin level was found in children with higher concentration of the hormone before the training and a lower decrease in children with higher growth of fat mass during the period without exercises. The result complies with the assumption that higher fat mass should indicate a need to lower one's appetite. The authors of the research speculate that a decrease in leptin concentrations could result from changes in the organism energy balance (47).

Summarising the results of the listed researches, it can be stated that a decrease of leptin level after short-term and intensive exercises took place when the physical effort was extreme and energy expenditure exceeded about 800 kcal (26, 34, 36, 40, 48). Whereas, exercises lasting more than 60 minutes resulted in a decrease of leptin, delayed up to 48 hrs after the training that was believed to be caused by potential influence of energy balance disorders in the organism (26, 33-36, 40). In case of long-term exercises, the obtained results are ambiguous. Some of the scientists did not observe changes in leptin concentration caused by the exercises (41, 42), while the others noticed appearance of changes in the hormone level, regardless of fat mass reduction (44, 46, 47).

The results obtained in the present work allowed a conclusion that both waist circumference (WC) and the logarithm of the sum of three skinfolds (log SF), as well as body composition parameters: %BF, FM, FFM are significantly connected with the level of leptin. Dividing the examined girls into two homogenous groups exposed mutual dependencies between concentration of the determined hormone and the abovementioned parameters.

Formerly conducted researches indicated similar relations. Leal-Cerro *et al.* (35) found a strong correlation between leptin and body mass, BMI and FM in both the control group and the exercising one. In the research performed by Perusse *et al.* (43) the levels of leptin in both males and females were strongly correlated with %BF. Okazaki *et al.* (46) demonstrated a close connection of leptin with BMI and FM. Also in obese children a strong correlation was found between leptin and body mass, FM, FFM and %BF (47). Another experiment analysing the organism preparatory processes for increased load caused by physical effort showed a significantly lower leptin concentration in blood serum in females after 10-week training (twice a week, 60 min at 60% VO_2 max). A decrease of leptin level resulted from fat tissue reduction caused by intensive swimming training (49). Also there was examined the influence of swimming endurance training on leptin level and obesity gene expression *(ob)* combined with insulin secretion, body composition and supply of energy with nutrition. Male rats of Wistar breed were randomly divided into two groups: the exercising one and the non-exercising one. After 9 weeks of training there was a 10% decrease of body mass, 55% decrease of fat mass, 55% decrease of insulin level and 56% decrease of leptin level. However, the influence of training on *ob* gene expression in m-RNA of the animals fat tissue was not observed. At the same time it was found that the total fat mass (50) was the best factor to be the base for anticipation of leptin level decrease. Similar results were obtained in the present work where the value of %BF was an important harbinger of leptin content. The result allows to conclude that long-term and regular adaptation of organism for increased physical activity leads to an increase of metabolism of fat tissue, and consequently to a decrease of %BF that resulted in lowering leptin level in training girls. Apart from leptin, also the WHtR index, indicating relation of waist circumference to body height, demonstrated a strong connection with physical activity. WHtR was significantly lower (thin girls) in upper (IV) quartile of physical activity and inversely proportional to the level of physical activity in relation to the whole group. The result showed that WHtR is strongly correlated with physical activity which was not found in case of BMI. Klein-Platat *et al.* (51) examining an influence of physical activity on values of obesity indices in 12-year-old French teenagers found a relation between BMI and physical activity only in girls. It might have resulted from higher physical activity of boys, therefore a possibility to develop bigger muscle mass which is not taken into account by BMI (2-4, 7). Assessment of obesity level with the use of the WHtR index allows better examination of proportionality of adipose tissue distribution. That is why measurements of waist circumference and WHtR can be more effective indices of abdominal obesity and consequently anticipate the risk of cardio-vascular diseases in children and teenagers better than the BMI. Though, it should be taken into consideration that both WHtR and BMI are affected by age and sex during the puberty period. A considerable decrease of WHtR was observed between 5th and 16th year of life, reflecting differences in the growth rate and waist circumference (51-53).

Higher values of BMI, WHtR and WC can indicate not only a higher risk of obesity prevalence but also an excessive accumulation of fat tissue in the central body part (abdominal obesity).

A negative phenomenon observed recently is a decrease of daily physical activity during pubescence from childhood to adolescence (3, 7).

The latest research by Thibault *et al.* (2), as well as in some other studies, it was observed that girls are less physically active than boys and moderate and intensive physical activity in girls is an important factor in body mass control (2-4, 7, 51). The problem is particularly significant in the aspect of physical fitness of growing up teenagers. It was examined that 15 and 16-year-old overweight girls demonstrate lowered cardio-vascular efficiency, muscle endurance, speed and agility. Moreover, even highly physically active overweight people do not achieve physical fitness higher than average. It results from a negative relation between overweight and physical fitness (5). Due to the fact that physical activity significantly modifies the influence of genetic factors on the BMI and WC, a high level of physical activity is especially beneficial in case of genetic susceptibility to obesity, and physically active life-style can neutralize the predispositions (54). Fleich *et al.* (20) claimed that in children with high risk of obesity high values of BMI and FM in adulthood were connected with an increase of body mass. Additionally, a high concentration of leptin, regardless of BMI and FM, also anticipated higher BMI and FM after 4 years. Shih and Lion (55) determined concentration of plasmatic leptin as a factor predicting the quantity of weight fall at application of a diet, moderate physical activity and health education.

It can be concluded the systematic physical activity is an essential element of a healthy life-style and a determinant of proper development during the puberty period in children and teenagers.

The authors hope that continuation of the researches will enable better understanding of: 1) the influence of physical exercises on the level of leptin and body fatness; 2) reaction and correlation of the discussed factors in connection to the problem of obesity; 3) connection between levels of physical activity and leptin content in relation to the age of the examined girls.

CONCLUSIONS

In summary, we conclude that long-term and intensive physical effort is an important factor influencing leptin secretion and body mass reduction in the examined girls.

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