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Correlations of Skinfold Thicknesses and Circumferences at Exactly Defined Body Sites with Leptin in 10-12-Year-Old Boys with Different BMIs

Antonio Cicchella[1], Toivo Jürimäe[2], Claudio Stefanelli[1], Priit Purge[2], Evelin Lätt[2] and Meeli Saar[2]

[1] University of Bologna, Department of Sciences for Quality of Life, Rimini, Italy
[2] University of Tartu, Faculty of Exercise and Sport Sciences, Tartu, Estonia

A B S T R A C T

The aim of this study was to investigate the correlations of leptin with values of skinfold thicknesses and circumferences in 10–12-year-old boys (N=248) and these correlations were additionally studied in boys with different BMI subgroups[12] (normal N=190, overweight N=34 and obese N=24). In total, 9 skinfolds and 13 circumferences were measured using the recommendations of ISAK. Fasting leptin concentrations were also determined. No significant differences emerged between the three subgroups in age and Tanner stage. Skinfold thicknesses, circumferences and leptin concentrations were significantly higher in overweight and obese groups. In the total group, the correlation (partial correlation, eliminating age and Tanner stage) between separate skinfold thicknesses and leptin was higher than r=0.70. The sum of 9 skinfold thicknesses correlated significantly to leptin in all groups (r=0.558–0.779). In the obese group, triceps, biceps and front thigh skinfold thicknesses did not correlate (p>0.05) with leptin. In the total group, all measured circumferences correlated significantly to leptin concentration (r=0.328–0.724). However, in the obese group, the measured circumferences did not correlate to leptin (p>0.05). Waist-to-hip ratio correlated with leptin only in the total group of boys. It was concluded that as a rule, close correlations emerged between leptin and skinfold thicknesses and circumferences. The strongest correlation with leptin was found with the sum of 9 skinfolds and waist-to-hip ratio.

***Key words**: skinfold thicknesses, circumferences, BMI, leptin, boys*

Introduction

Previous studies indicate that adipocytokines play a fundamental role in the development of obesity[1]. Among classical adipocytokines, leptin emerges as the most prominent marker in children of the possibility to develop obesity. Leptin was discovered as the product of a gene expression of the ob/ob mice and it is an adipocyte-derived 16-kDa hormone, produced by white adipose cells and among other functions, has the capacity to regulate appetite, acting on the CNS receptors probably through its action on the neuropeptide Y[2]. Leptin expression is greater in subcutaneous than in omental adipose tissue[3]. Very few studies have investigated the possible correlation of circulating leptin with the distribution of subcutaneous adipose tissue (skinfold thicknesses and circumferences) in boys[3]. The correlation of leptin and body fat mass is well known[4,5]. Leptin was also proven to be positively correlated with the change in BMI in obese humans[6]. Leptin is mainly produced in white adipose tissue and circulates as the content of adipose tissue[7]. Further, leptin concentration reflects body fat mass[5,8] and might be considered as a reliable marker of adipose tissue, body mass, and energy homeostasis[6].

A significant correlation was found between leptin and BMI and the sum of skinfold thicknesses in young children[7] and adolescents[9]. In different studies the sum of skinfolds were used as indirect indicator of total body fat[7,8]. However, there are no data available about correlations between leptin and single skinfold thicknesses. We hypothesised that skinfolds measured in trunk (abdominal) region have the highest correlations with leptin be-

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cause in this area the fat mass and lipolytic activity are the highest.

There is very few information available about the correlation of leptin with the second indirect measure of body fatness, the body segments circumferences. More information can be yielded about the correlation between leptin and waist and hip circumferences and waist-to-hip ratio. Kettaneh et al.[4] in a sample of prepubertal boys found that baseline levels of leptin were significantly correlated with both waist (r=0.62) and hip (r=0.53) circumferences and with waist-to-hip ratio (r=0.73). In this study[4] leptin predicted also the increase in the hip circumference of children at one-year follow-up (r=0.22). Sudi et al.[10] found a significant correlation between leptin and waist-to-hip ratio in obese boys (r=0.74) and separately with waist (r=0.62) and hip (r=0.65) circumferences. There is no information about the suggested possible correlation of leptin with other limbs or trunk circumferences. We hypothesized that there are higher correlations between leptin and waist-to-hip ratio which more or less characterize total body fat. The influence of other circumferences is still unknown. Skinfold thicknesses were measured as compressed subcutaneous adipose tissue and circumferences were measured as a non-compressed tissue together with bone and other soft tissues (as a rule, muscle tissue)[11]. On the other hand, the issue of the stability of these possible correlations in different BMI groups of boys (from normal to obese) arose. In low BMI boys, the correlation between BMI and fat mass is due to the muscle mass development probably lower with leptin, because different BMI values do not define the same level of adiposity. The aim of this study was to compare possible correlations of leptin with values of skinfold thicknesses and circumferences in different BMI groups of 10–12-year-old boys.

Materials and Methods

Subjects

The subjects of this study were from a cross-sectional sample of 248 boys (age 10–12 years) from different schools from the city of Tartu and surroundings (Estonia). This study was conducted as part of a longitudinal pediatric metabolic syndrome study. The subjects were considered as a non-selected total group and were also distributed according to Cole et al.[12] into three BMI subgroups: normal weight, N=190 (BMI<19.8–21.9); overweight, N=34 (BMI<24–26.8) and obese N=24 (BMI≥ 24–26.8). The boys were not using any medications during the study period. All boys were free from infections and took part at least for 2–3 times per week in the compulsory physical education lessons at school, 45 min each, or taking additionally part in different sport-school sections. All boys and their parents gave their written informed consent to participate in the study. The study was approved by the Medical Ethical Committee of the University of Tartu (Estonia).

Anthropometric measurements

Body height was measured using a Martin metal anthropometer to the nearest 0.1 cm with a standard technique. Body mass was measured with minimal clothing to the nearest 0.05 kg using a medical electronic scale (A&D instruments, Abingdon, UK) and BMI was calculated as body mass (kg) divided by body height squared (m^2). Pubertal development of the boys was assessed based on the self-assessment according to the Tanner classification method[13].

All skinfold thicknesses and circumferences were measured according to the protocol recommended by the International Association for the Advancement of Kinathropometry (ISAK)[14]. In total, 9 skinfolds (biceps, subscapular, triceps, iliac crest, supraspinale, abdominal, front thigh, medial calf, and mid axilla) were measured twice with a Holtain (Crymmych, UK) skinfold calliper at the right side of the body with limbs relaxed. If the difference between the 2 measurements was >2 mm, a third measurement was taken and the 2 closest measurements were averaged. Nine skinfold thicknesses were also summarized as an indicator of total body fat.

Thirteen circumferences (head, neck, arm relaxed, arm flexed and tensed, forearm, wrist, chest, waist, hip, mid-thigh, thigh, calf and ankle) were measured twice using a metal tape from Centurion kit (Rosscraft, Canada). Waist-to-hip ratio was calculated. Both skinfold thicknesses and circumferences were measured by a well-trained anthropometrist.

TABLE 1
BASIC AND ANTHROPOMETRIC DATA OF THE SUBJECTS (X±SD)

Variables	Total (N=248)	Normal (N=190)	Overweight (N=34)	Obese (N=24)
Age (years)	11.18±0.65	11.16±0.65	11.13±0.56	11.36±0.74
Body height (cm)	149.5±7.7	148.5±7.5	151.7±6.4*	155.1±8.4*
Body mass (kg)	43.3±11.9	38.4±6.0	52.6±5.7*	69.4±11.6*#
BMI (kg/m²)	19.2±4.2	17.3±1.7	22.7±1.5*	29.2±3.2*#
Leptin (ng/mL)	7.63±10.92	3.38±4.10	13.71±8.14*	32.61±13.91*#
Tanner stage (1/2/3/4/5)	2.0±0.6 52/154/40/2/0	1.9±0.7 46/115/27/2/0	2.2±0.6 4/21/9/0/0	2.1±0.5 2/18/4/0/0

*Significantly different from the normal BMI group, $p<0.05$; #Significantly different from the overweight group, $p<0.05$

Leptin measurements

A 10 mL blood sample was obtained from the antecubital vein with the participant sitting in an upright position in the morning (8–9 a.m.) after an overnight fast. The serum was separated and frozen at –80 °C for later analysis, which was completed within 6 month from collection. Leptin concentrations were determined by an ELISA sandwich method using a kit from Mediagnost GmbH (Reutlingen, Germany). The intra- and inter-assay CVs were less than 10%.

Statistical analysis

Statistical analysis was performed with SPSS 18.0. Normal distribution of data was controlled and data which were not normally distributed were log transformed. Descriptive statistics (mean ±SD) were calculated. Differences between groups were analyzed using ANOVA (LSD post-hoc). Partial correlation was used to find correlations between leptin concentration, skinfolds and circumferences after controlling for age and pubertal status. Stepwise regression analysis was performed to find out which measured parameter predicts leptin concentration most after controlling for pubertal status and age. Leptin was inserted in the model as dependent parameter, skinfolds and circumferences were inserted as independent parameters. Only parameters which correlated significantly to leptin were inserted in the model. The level of significance was set at $p<0.05$ for all statistical analyses.

Results

Mean leptin, anthropometric parameters, skinfold thicknesses and circumferences are presented in Tables 1 and 2. There were no significant differences ($p>0.05$) between the three subgroups in age and Tanner stage. All other parameters (skinfold thicknesses, circumferences and leptin concentrations) were significantly different between normal, overweight and obese groups in all cases. Especially high mean leptin concentration was observed in obese group (Table 1).

TABLE 2
MEAN (±SD) SKINFOLD THICKNESSES AND CIRCUMFERENCES IN THE TOTAL, NORMAL, OVERWEIGHT AND OBESE GROUPS OF BOYS

Variables	Total (N=248)	Normal (N=190)	Overweight (N=34)	Obese (N=24)
Skinfold thicknesses (mm):				
Triceps	11.6±5.9	9.1±3.2	16.7±4.6*	23.8±4.0*#
Subscapular	8.6±6.4	5.8±2.3	14.2±6.2*	22.0±6.5*#
Biceps	6.4±4.0	4.7±2.1	9.9±3.3*	14.9±2.4*#
Iliac crest	16.1±10.7	11.6±6.4	27.3±8.0*	35.5±7.9*#
Supraspinale	9.9±8.4	6.2±3.2	17.5±6.4*	27.8±8.5*#
Abdominal	13.0±9.6	8.9±5.1	22.9±7.8*	31.2±7.6*#
Front thigh	17.6±9.7	13.4±5.0	25.9±6.2*	38.9±5.9*#
Medial calf	12.2±6.4	9.7±3.5	16.3±3.9*	25.9±6.7*#
Mid-axilla	8.0±6.5	5.2±2.7	13.4±5.3*	22.3±6.0*#
Sum of 9 skinfolds	103.1±64.1	74.6±29.6	164.2±42.8*	242.3±43.4*#
Circumferences (cm):				
Head	54.2±1.7	53.9±1.6	54.8±1.6*	56.0±1.4*#
Neck	29.4±2.4	28.6±1.7	31.2±1.9*	33.5±2.2*#
Arm flexed	23.8±3.6	22.4±2.1	27.0±2.1*	31.1±2.5*#
Arm relaxed	22.2±3.7	20.7±2.1	25.6±2.0*	29.8±2.6*#
Forearm	21.5±2.0	20.7±1.2	23.1±1.2*	25.5±2.0*#
Wrist	14.2±1.1	13.9±0.8	15.0±0.8*	16.1±1.1*#
Chest	74.2±8.2	70.9±4.6	81.2±5.2*	90.9±7.1*#
Waist	65.1±9.4	61.0±4.4	73.0±5.5*	86.0±7.9*#
Hip	78.2±9.0	74.5±5.0	86.0±4.7*	96.7±7.6*#
Thigh	46.1±7.2	43.0±3.8	52.3±3.6*	61.7±5.3*#
Mid- thigh	42.6±6.0	40.1±3.4	47.7±3.1*	55.2±4.5*#
Calf	30.3±3.6	28.9±2.2	33.1±2.0*	37.7±3.3*#
Ankle	20.7±2.2	19.9±1.5	22.2±1.3*	24.4±2.8*#
Waist-to-hip ratio	0.83±0.05	0.82±0.04	0.85±0.05*	0.89±0.73*#

* Significantly different from the normal BMI group, $p<0.05$; # Significantly different from the overweight group, $p<0.05$

TABLE 3
PARTIAL CORRELATIONS BETWEEN LEPTIN, SKINFOLDS AND CIRCUMFERENCES IN BOYS AFTER CONTROLLING FOR PUBERTAL STATUS AND AGE

Variables	Total (N=248)	Normal (N=190)	Overweight (N=34)	Obese (N=24)
Body height	0.210***	0.084	–0.221	–0.019
Body mass	0.663***	0.305***	0.161	0.294
BMI	0.715***	0.402***	0.386*	0.285
Skinfold thicknesses:				
Triceps	0.741***	0.523***	0.768***	0.332
Subscapular	0.745***	0.487***	0.521**	0.433*
Biceps	0.741***	0.486***	0.562***	0.191
Iliac crest	0.768***	0.531***	0.592***	0.444*
Supraspinale	0.747***	0.468***	0.595***	0.524*
Abdominal	0.746***	0.516***	0.697***	0.505*
Front thigh	0.740***	0.506***	0.682***	0.123
Medial calf	0.652***	0.387***	0.480**	0.689***
Mid-axilla	0.744***	0.460***	0.738***	0.451*
Sum of 9 skinfolds	0.779***	0.558***	0.755***	0.561**
Circumferences:				
Head	0.328***	0.124	0.259	0.103
Neck	0.486***	0.031	0.466**	0.232
Arm flexed	0.683***	0.333***	0.642***	0.187
Arm relaxed	0.694***	0.363***	0.676***	0.246
Forearm	0.606***	0.239***	0.325	0.099
Wrist	0.449***	0.016	0.250	0.041
Chest	0.640***	0.238**	0.469**	0.401
Waist	0.702***	0.373***	0.481**	0.344
Hip	0.696***	0.395***	0.489**	0.353
Thigh	0.724***	0.444***	0.564***	0.334
Mid-thigh	0.691***	0.382***	0.423*	0.366
Calf	0.609***	0.231**	0.160	0.326
Ankle	0.495***	0.107	0.384*	0.265
Waist–to–hip ratio	0.333***	0.020	0.190	0.038

* p<0.05; **p<0.01; ***p<0.001

From the anthropometric parameters, body height was correlated to leptin only in the total group, but not in the three subgroups (Table 3). Body mass correlated significantly with leptin only in the total and normal BMI groups and finally leptin did not correlate significantly with the BMI in the obese group (Table 3). In the total group, the correlation between separate skinfold thicknesses and leptin were higher than r=0.70 (except for medial calf, Table 3). In subgroups of normal and overweight boys, the correlations between all skinfold thicknesses and leptin were significant (Table 3). In the obese group, the same correlations with triceps, biceps and front thigh skinfolds were not significant (p>0.05, Table 3). The sum of 9 skinfold thicknesses correlated significantly with leptin in all groups (r=0.558–0.779, Table 3).

In the total group, all measured circumferences significantly (p<0.001) correlated with leptin (Table 3; r= 0.328–0.724). In the normal BMI group, leptin correlation with head, neck, wrist and ankle circumferences was not significant. In the overweight group head, forearm, wrist and calf circumferences did not correlate significantly with leptin (Table 3). Surprisingly, in the obese group no measured circumferences significantly correlated with leptin (Table 3). Waist-to-hip ratio correlated significantly with leptin only in the total group (Table 3).

Stepwise regression analysis results are presented in Table 4. All skinfold thicknesses and circumferences were used in separate groups. In the total group, the sum of 9 skinfolds was the main predictor of leptin concentration (R^2x100=30.7%). From the circumferences, thigh and wrist were the most important (R^2x100=28.9%). In the normal weight group, the sum of 9 skinfolds together with supraspinale skinfold thickness characterized best the leptin concentration (R^2x100=33.1%). From the circumferences, the most important ones were those of thigh and calf (R^2x100=23.9%). In the overweight group,

TABLE 4
STEPWISE REGRESSION ANALYSIS BETWEEN LEPTIN AND SKINFOLD THICKNESSES AND BETWEEN LEPTIN AND CIRCUMFERENCES AFTER ADJUSTING FOR PUBERTAL STATUS AND AGE

Model	R^2x100	β	p
Total (N=248)			
Sum of 9 skinfolds	30.7	0.545	<0.001
Thigh circumference	28.9	0.663	<0.001
Wrist circumference		–0.390	<0.001
Normal (N=190)			
Sum of 9 skinfolds	33.1	0.813	<0.001
Supraspinale skinfold		–0.283	0.067
Thigh circumference	23.9	0.693	<0.001
Calf circumference		–0.317	0.004
Overweight (N=34)			
Triceps skinfold	66.4	0.697	<0.001
Arm relaxed circumference	55.6	0.655	<0.001
Obese (N=24)			
Medial calf skinfold	49.0	0.688	<0.001
Circumference	–	–	–

from the skinfold thicknesses the highest predictor of leptin concentration was triceps (R^2x100=66.4%) and arm relaxed circumferences (R^2x100=55.6%). In the obese group, the medial calf skinfold thickness characterized leptin concentration by 49.0%. No significant relationships between the measured circumferences and leptin were found in the obese group (Table 4).

Discussion and Conclusions

The results of this study indicate that in the total and normal BMI groups the sum of 9 skinfolds was highly correlated with leptin in boys. In the overweight and obese groups, the most important skinfolds were triceps and medial calf, respectively. From the circumferences, the most important one was the thigh circumference (together with wrist) in the total and normal (together with calf) groups. In the overweight group only arm relaxed circumference was selected and in the obese group no significant correlations between circumferences and leptin concentration emerged. It is interesting that in the overweight and obese groups the parameters selected for the model were only the measurement points in limbs.

Our results were expected, because leptin concentration is dependent first of all on the sum of 9 skinfolds which explains total subcutaneous fat tissue mass. However, in the overweight and obese groups some results were difficult to explain. Several researchers have found strong positive correlations for leptin with BMI, % body fat and fat mass in children and adolescents[15,16]. Leptin is mainly produced in white adipose tissue. It can be seen as a proportion if the size of the adipocytes[7]. However, there is very few information available about the influence of subcutaneous fat distribution on leptin concentration in children and adolescents with different BMI. In our study, all 9 measured skinfold thicknesses correlated significantly with leptin in the total, normal and overweight groups (Table 3).

In the total and normal BMI groups the most important predictor of leptin concentration was the sum of 9 skinfolds (Table 4). This is in accordance with other studies indicating that the fat distribution is not so important as the total fat mass[8]. It is difficult to explain the relatively low (but as a rule significant) correlations between leptin and different skinfold thicknesses in the obese group (Table 3). Using stepwise multiple regression analysis only medial calf was selected in the correlation with leptin (Table 4).

Using the same age and BMI groups as our obese boys, Sudi et al.[10] concluded that subcutaneous adipose tissue layers (15) measured as non-compressed fat tissue by using a Lipometer[17,18], significantly correlated with leptin in obese boys. However, in lean pubertal boys, weak correlations were found between adiposity measures and leptin[19]. In our study, in the total, normal and overweight groups all measured skinfold thicknesses correlated significantly with leptin. In the obese group, triceps, biceps and front thigh skinfolds did not correlate significantly with leptin (Table 3).

Several parameters may influence the correlations between leptin and fat measures (skinfold thicknesses and circumferences) in boys. It has been established that leptin levels in prepubertal boys are increased during the beginning of pubertal development and then remain stable in spite of increasing BMI[20]. However, Roemmich and Rogol[21] concluded that leptin concentrations reflect the size of the subcutaneous fat depot better than total fat mass or abdominal visceral fat in boys. The peak of leptin concentration between 11 and 13 years was shown in 11-year-old boys[18]. During the Tanner stage two of puberty, both fat free mass and fat mass increase[22].

There are some limitations in our study. Some measurement errors may have occurred using skinfold callipers or tapes for measuring subcutaneous adipose tissue thicknesses and circumferences, especially in the overweight and obese groups, calling for a respective comparison with the DXA method. We did not take into account the food intake in our subjects and their physical activity was poorly measured. The novelty of our complex study was that for the first time the detailed skinfold thicknesses (9 skinfolds), and especially 13 circumferences were used in the analyses of the same subjects. At present, no complex studies where skinfold thicknesses and circumferences are compared together as parameters of body fat distribution in boys have been conducted.

To our knowledge, this study is the first to present evidence for the correlations between leptin and separate skinfold thicknesses and circumferences in boys. Our study indicates that in future studies investigating the correlations between leptin and fat mass development, the subcutaneous fat mass should be measured as accurately as possible. From the two indirect measurement methods used, the sum of 9 skinfolds is more acceptable compared to the measurement of circumferences in different (mixed) groups of pubertal boys in the context of establishing the correlation with leptin.

The waist and hip circumferences and the ratio of these two parameters are frequently used for predicting coronary artery risk factors. In our study, the separate waist and hip circumferences correlated significantly with leptin in all groups, except the obese (Table 3). In previous studies, waist and hip circumferences have not correlated with leptin after adjustment for fat mass in obese children[10]. The waist-to-hip ratio did not correlate significantly with leptin in 13-year-old boys[4]. However, waist circumference correlated significantly with leptin ratio in Indians[6, 23]. On the other hand, waist circumference has been found to correlate more to visceral fat than to the total body fat[24].

In conclusion, our study indicates that leptin concentration is highly dependent on the skinfold thicknesses and circumferences in the total and normal BMI groups of boys. In the overweight and obese subgroups this correlation is not so strong. As a rule, the measured parameters in limbs are not sensitive of leptin concentration. In the obese the circumferences do not correlate significantly with leptin.

The main finding of the current study was that all measured skinfold thicknesses and circumferences correlated highly with leptin in the total group. However, in the normal BMI group the measured circumferences of very low fat mass (head, neck, wrist and ankle) did not correlate with leptin significantly. It is acceptable to measure skinfold thicknesses and circumferences in the normal BMI groups only. Especially in very obese boys better methods are needed for the measurement of body fat, because BMI is more an indicator of »overweight« than »obese«. Basically, close correlations were established in our study between leptin and the measured skinfold thicknesses (9) and circumferences (13) in boys. However, in obese boys the measured circumferences were not a significant parameter for leptin. When comparing the total and normal BMI groups of boys, the most important parameter is probably the sum of 9 skinfolds, characterizing the topography of total skinfold thicknesses. This is partially attributable to the higher error of measurement of skinfolds at high levels of adiposity and lower reproducibility in children[25].

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T. Jürimäe

University of Tartu, Faculty of Exercise and Sport Sciences, Jakobi 5, 51006 Tartu, Estonia
e-mail: Toivo.Jurimae@ut.ee

KORELACIJE DEBLJINA KOŽNIH NABORA I OPSEGA NA ODREĐENIM DJELOVIMA TIJELA S LEPTINOM U DJEČAKA OD 10 DO 12 GODINA S RAZLIČITIM INDEKSIMA TJELESNE MASE

SAŽETAK

Cilj ovog istraživanja bio je istražiti korelaciju leptina s vrijednostima debljina kožnih nabora i opsega u dječaka od 10 do 12 godina (N=248), a ove korelacije dodatno su istražene u podrgupama dječaka s različitim indeksima tjelesne mase (normalni N=190, prekomjerni N=34, i pretili N=24). Ukupno, 9 kožnih nabora i 13 omjera opsega mjereni su na temelju preporuke ISAK-a. Također, određene su koncentracije leptina na tašte. Nema značajne razlike između tri podskupine dobi i stadiju Tanner. Debljine kožnih nabora, omjeri opsega i koncentracija leptina značajno je viša u skupina prekomjerne težine i pretilih. U sveukupnom uzorku, korelacija (djelomična povezanost, eliminirajući dob i Tanner stadij) između odvojenih debljina kožnih nabora i leptina bio veći od r=0,70. Zbroj 9 debljina kožnih nabora značajno korelira s leptinom u svim skupinama (r=0,558–0,779). U pretiloj skupini, debljine kožnih nabora tricepsa, bicepsa i prednjeg bedra nije u korelaciji (p>0,05) s leptinom. U ukupnom uzorku, svi omjeri opsega značajno koreliraju s mjerenom koncentracijom leptina (r=0,328–0,724). Međutim, u skupini pretilih, izmjereni omjeri opsega ne koreliraju s leptinom (p>0,05). Omjer opsega struk i kuka u korelaciji je s leptinom samo u ukupnom uzorku dječaka. Zaključeno je da u pravilu, bliska povezanosti pojavljuje se između leptina, debljinama kožnih nabora i opsega. Najjača korelacija s leptinom pronađena je zbrojem 9 kožnih nabora i omjerom opsega struka i kuka.