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The relationship between adiposity parameters and C-reactive protein values in overweight and obese women

Odnos između parametara gojaznosti i vrednosti C-reaktivnog proteina kod predgojaznih i gojaznih žena

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Abstract

Background/Aim. Overweight/obesity has become important health problem in developed countries. It may be related to a presence of low-grade inflammation in white adipose tissue. The aim of this study was to investigate the levels of inflammatory marker C-reactive protein (CRP) and its relation to anthropometric parameters in overweight and obese females. **Methods**. This study included 200 apparently healthy, overweight and obese women (18–45 years). Their standard and alternative anthropometric parameters [body mass index (BMI), percentage of fat (%F), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), body adiposity index (BAI)] were determined and correlated to serum CRP concentration. **Results.** Average CRP level was 5.56 ± 2.43 mg/L, and it significantly positively correlated to all investigated anthropometric parameters. There was significant difference between overweight and obese group in all investigated anthropometric parameters, as well as in CRP values. When investigated separately, according to BMI, values regarding obese females showed significant correlation between CRP and every investigated anthropometric parameter. In overweight subjects, no such correlation was recorded. In the obese group, all investigated parameters were significantly related to F. In overweight subjects, body weight (BW), BMI, WC and WHtR showed significant relation to F. **Conclusion.** The significant difference between the overweight and obese group in all parameters of central obesity was found as well as in the CRP levels. In the obese group, we found strong correlation between adiposity measured by fat percentage and parameters of central obesity, while in the overweight group WHR and BAI did not correlate to fat percentage. Our results confirmed that CRP is a valuable marker of metabolic risk in obese females, and BMI, although not so new, is still reliable parameter of adiposity.

Key words:
obesity; overweight; women; anthropometry; c-reactive protein.

Apstrakt

Uvod/Cilj. Prekomerna telesna masa i gojaznost postali su značajan zdravstveni problem u razvijenim zemljama, a mogu biti povezani sa prisustvom hronične inflamacije niskog intenziteta u belom masnom tkivu. Cilj rada bio je da se ispitaju nivoi markera inflamacije, C-reaktivnog proteina (CRP), i njegova povezanost sa standardnim antropometrijskim parametrima kod predgojaznih i gojaznih žena. **Metode.** Studijom je bilo obuhvaćeno 200 zdravih žena (18–45 god) kojima su određeni standardni i alternativni antropometrijski parametari [indeks telesne mase (BMI), procenat masti (%F), obim struka (WC), odnos obima struka i kukova (WHR), odnos obima struka i visine (WHtR), kao i indeks telesne masnoće (BAI)] koji su zatim korelisani sa koncentracijama CRP u serumu. **Rezultati.** Prosečna vrednost nivoa CRP u serumu u celoj grupi iznosila je 5,56 ± 2,43 mg/L i utvrđena je njegova značajna pozitivna korelacija sa svim ispitivanim antropometrijskim parametrima. Uočena je statistički značajna razlika između grupa predgojaznih i gojaznih žena u svim ispitivanim antropometrijskim parametrima, kao i u pogledu koncentracije CRP. U grupi gojaznih ispitanica utvrđena je značajna povezanost između CRP i svih antropometrijskih parametara, dok u predgojaznoj grupi nije zabeležena statistička značajnost. U grupi gojaznih, svi antropometrijski pokazatelji pokazali su značajnu korelaciju sa procentom telesne masti, a kod predgojaznih žena, korelacija je bila značajna samo za telesnu masu, BMI, WC i WHtR. **Zaključak.** Između predgojaznih i gojaznih ispitanica postoji značajna razlika u pogledu svih pokazatelja centralne gojaznosti, kao i u pogledu

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koncentacije CRP u serumu. U grupi gojaznih, pokazana je značajna korelacija između sadržaja masti, izraženog kao procenat masnoće, i svih pokazatelja visceralne distribucije masti, dok u grupi predgojaznih značajna povezanost nije urađena za WHR и BAI. Naši rezultati potvrđuju da CRP može predstavljati značajan marker metaboličkog rizika kod gojaznih žena, kao i da je BMI, iako spada u tradicionalne parametre, i dalje pouzdan pokazatelj sadržaja telesne masti.

Ključne reči:
gojaznost; telesna masa, prekomerna; žene; antropometrija; c-reaktivni protein.

Introduction

Overweight/obesity has become important health problem in developed countries. It may be related to presence of low-grade inflammation in white adipose tissue [1]. Precise mechanisms of chronic inflammation induction in obesity as well as the relation between obesity and inflammatory markers are yet to be explained [1, 2]. So far, the importance of C-reactive protein (CRP), as the most versatile inflammatory marker, is still in the spotlight.

CRP is acute-phase protein and inflammatory marker. Increased concentrations of CRP are present in serum after tissue injury, infection and inflammation [3]. Its synthesis takes place in liver, and is mostly regulated by interleukin-6 (IL-6). Numerous surveys classified CRP as important marker of inflammation, which may indicate early vascular lesions, and may be a predictor of cardiovascular events, even in apparently healthy population [4]. Most of the studies confirm that even levels below the accepted upper physiological limits (1 mg/dL) may indicate the increased risk of heart and cerebral stoke, peripheral atherosclerosis, and sudden death in both gender [1, 5, 6]. CRP outstands as independent risk factor, apparent from traditional risk factors such as increased total cholesterol, increased levels of glucose and homocystein, hypertension, age, high body mass index (BMI), smoking and physical inactivity [7].

In general, recent studies indicate that white adipose tissue produces numerous mediators, for example, cytokines tumor necrosis factor alpha (TNFα) and IL-6. In addition, in obese persons, white adipose tissue is infiltrated by macrophages with increased local production of proinflammatory mediators. These factors promote acute phase reaction and chronic inflammation in obese persons [4].

However, some authors proposed the existence of a subgroup of obese persons who are metabolically normal (without increased risks of heart diseases, type 2 diabetes, hypertension, stroke, gallbladder disease, cancers, etc.) [8]. They hypothesize that in this subpopulation obesity seems to be uncomplicated and is characterized by early onset, hyperplasticity of otherwise normal adipocytes, and peripheral type of fat distribution. The inflammation in these persons should be absent, and they supposed to have normal levels of inflammatory markers.

The aim of this study was is to investigate the levels of inflammatory marker CRP and its relation to standard anthropometric parameters [body mass (BM), BMI, percentage of fat (F), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR)], as well as to alternative parameter, the body adiposity index (BAI), in population of apparently healthy overweight and obese females.

Methods

This study enrolled 103 overweight (BMI between 25 and 29.9 kg/m^2) and 97 obese (BMI ≥ 30 kg/m^2) females, nonsmokers, aged 18–45 years, without any comorbidities, and with regular menstrual cycles. Our study did not include persons with: clinically confirmed hypertension, glucose intolerance or diabetes, other endocrine or systemic inflammatory diseases, cardiovascular and/or cerebrovascular diseases, malignant diseases, pregnancy, and those with CRP values higher than 10 mg/L at the moment of investigation. None of them had previous history of stroke, transitory ischemic attack, angina pectoris, heart stroke, or congenital heart abnormality. At the moment of investigation, they did not take any medical drugs, supplements, oral contraceptives, or hormonal substitution drugs. Investigation was approved by the local Ethical Committee and was conducted in Department of Nutrition, Institute of Hygiene, Military Medical Academy, Belgrade, Serbia, during 2013 and 2014.

Standard anthropometric measurements were performed: body weight (BW), body height, WC and hip circumference [9], skinfold thickness, and followed parameters were calculated: BMI [kg/m^2], percentage of fat (%F) [10], waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) [9], and BAI [hip circumference (cm)/height$^{1.5}$ (m) – 18] [11]. High sensitive CRP was measured in serum using enzymatic kits (Roche Diagnostics, Basel, Switzerland) on a Siemens autoanalyser (Dimension®, RxL Max, Siemens Dade Behring). Concentrations lower than 1 mg/L refer to low risk for cardiovascular diseases, values between 1 and 3 mg/L were in an average range, and values higher than 3 mg/L were considered as high risk [6]. WC less than 80 cm considered normal, between 80 and 87.9 cm referred to increased risk of metabolic complications, and ≥ 88 cm referred to substantially increased risk [9]; WHR ≥ 0.8 was also considered increased, as well as WHtR ≥ 0.62 [12].

Obtained data were statistically processed and presented as means ± SD; some of the data were presented as proportions (%). Difference between groups and correlation between chosen parameters and CRP values were analyzed by Student's *t*-test (χ^2 test for categories) and Spearman's rank correlation (r), respectively. Statistical significance was accepted at $p < 0.05$.

Results

Anthropometric parameters and serum concentrations of CRP in all 200 investigated subjects together are presented in Table 1.

Average CRP was 5.56 ± 2.43 mg/L, and significantly positively correlated to all investigated anthropometric parameters (BW: $r = 0.3329$, $p < 0.01$; BMI: 0.3567, $p < 0.01$;

Table 1

Anthropometric parameters and C-reactive protein (CRP) values of the study subjects

Parameters	$\bar{x} \pm SD$	min–max
Age (year)	31.12 ± 7.26	18–45
BW (kg)	87.99 ± 14.99	60.60–144.00
BMI (kg/m^2)	31.16 ± 5.08	25.04–51.24
%F	41.04 ± 4.98	28.70–56.00
WC (cm)	95.75 ± 12.98	70.00–148.00
WHR	0.85 ± 0.08	0.65–1.12
WHtR	0.57 ± 0.08	0.43–0.87
BAI	33.93 ± 4.99	23.06–50.40
CRP (mg/L)	5.56 ± 2.42	0.82–10.00

BW – body weight; BMI – body mass index; %F – fat percentage; WC – waist circumference; WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; BAI – body adiposity index; CRP – C-reactive protein.
$\bar{x}$ – mean value; SD – standard deviation.

%F: 0.2589, $p < 0.01$; WC: 0.3645, $p < 0.01$; WHR: 0.2417, $p < 0.01$; WHtR: 0.3637, $p < 0.01$, and BAI: 0.2063, $p < 0.05$).

Statistical analysis showed the significant difference between the overweight and obese group for all investigated anthropometric parameters, except for the age as well as CRP values (Table 2).

Moreover, when the overweight and obese groups were presented separately, according to BMI, the different correlation between anthropometric parameters and CRP values were found. The results are presented in Table 3.

In both groups, there was no statistically significant correlation between CRP levels and age. In addition, in overweight subjects, no significant correlation was recorded between CRP and any anthropometric measurement or index whatsoever. On the other hand, in the obese group, every investigated anthropometric parameter was significantly correlated to CRP levels.

Percentage of fat measures body adiposity. In both groups, age was not significantly correlated to this parameter. In the overweight subjects, neither WHR nor BAI showed significant relation to %F, opposite to BW, BMI, WC and WHtR. In the obese group, all investigated parameters were significantly related to %F.

Table 2

Anthropometric parameters and C-reactive protein (CRP) values in overweight and obese groups of women

Parameter	Overweight	Obese	*p*
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	
Age (years)	31.55 ± 7.66	30.69 ± 7.60	n.s.
BW (kg)	77.82 ± 6.89	98.80 ± 13.67	< 0.000
BMI (kg/m^2)	27.49 ± 1.35	35.05 ± 4.67	< 0.000
%F	38.23 ± 3.26	44.03 ± 4.75	< 0.000
WC (cm)	88.13 ± 6.94	103.84 ± 13.03	< 0.000
WHR	0.83 ± 0.07	0.87 ± 0.08	0.0011
WHtR	0.52 ± 0.04	0.62 ± 0.08	< 0.000
BAI	30.86 ± 2.55	37.19 ± 4.89	< 0.000
CRP (mg/L)	4.95 ± 2.29	6.21 ± 2.41	0.0002

For abbreviations see under Table 1.

Table 3

Spearman's correlation coefficient (r) in overweight and obese women

Parameter	Correlation to CRP, (r; *p*)		Correlation to %F; (r; *p*)	
	overweight	obese	overweight	obese
Age	-0.1225; n.s.	-0.0525; n.s.	-0.1152; n.s.	0.0843; n.s.
BW	0.0625; n.s.	0.3101; < 0.01	0.2000; < 0.05	0.6077; < 0.01
BMI	0.1927; n.s.	0.3103; < 0.01	0.4664; < 0.01	0.6179; < 0.01
WC	0.1206; n.s.	0.3628; < 0.001	0.3679; < 0.01	0.6366; < 0.01
WHR	0.0935; n.s.	0.2831; < 0.001	0.1693; n.s.	0.4566; < 0.01
WHtR	0.1493; n.s.	0.3455; < 0.001	0.4081; < 0.01	0.6096; < 0.01
BAI	0.0749; n.s.	0.2806; < 0.01	0.0749; n.s.	0.3776; < 0.01
F	-0.064; n.s.	0.2757; < 0.001		
CRP			-0.064; n.s.	0.2757; < 0.001

n.s. – non significant.
For abbreviations see under Table 1.

According to BMI, all subjects were overweight or obese. However, fat distribution was different: in the overweight group, 10 (9.7%) women had normal values of WC, in 52 (50.5%) women the recorded values were in the range of increased risk of metabolic complications and in 41 (39.8%) women substantially increased risk values were recorded. In the obese group, there was only 1 person with normal WC, 5 with values suggesting increased risk, and 91 (93.8%) with substantially increased risk. These differences were statistically significant ($p < 0.05$). When risk is estimated according to WHR, there were 37 (35.9%) subjects in the overweight group with normal WHR, and 66 (64.1%) with increased WHR. In the obese group, normal WHR was recorded in 17 (17.5%) subjects and increased WHR in 80 (82.5%). In the overweight group, all subjects had normal WHtR, while in the obese group 33 (34%) of them had increased risk, i.e. WHtR ≥ 0.62 ($p < 0.05$).

In addition, 2 persons in the overweight group had CRP concentration in the range of low risk, 15 persons in the range of average, and 86 (83.5%) in the range of high risk of cardiovascular disease development. In the obese group, increased values of CRP were recorded in 93 (95.9%) subjects, with 4 persons in average range and no subject in low risk range, but these differences were not statistically significant.

Discussion

Obesity is extensively spread disease, which is, due to its metabolic effects, considered the most frequent risk factor for development of diabetes, hypertension and atherosclerosis. However, obesity itself, when defined according to body mass, is less powerful predictor comparing to central obesity, so recently anthropometric parameters have been adopted in order to achieve better discrimination of body adiposity and metabolic risk. The accuracy and usefulness of numerous parameters were analyzed, such as WC, WHR, WHtR [12], and BAI [11].

The important difference between men and women regarding body fat storage is considering the fact that women have more adipocytes at the start of their adult life (hyperplastic obesity), so they may accumulate more fat compared to men [13]. Later, process of fat accumulation is particularly rapid in subcutaneous abdominal area as the result of adipocyte hypertrophy. These observations served as foundations for suggestions that, especially in young women, obesity without comorbidities might be present. In our study, all women were apparently healthy and relatively young (18–45 years). However, the average levels of CRP were elevated in both groups, particularly in the obese one, and the difference between groups was statistically significant.

Despite the absence of metabolic diseases, according to our results, average WC of all investigated subjects was 95.55 ± 12.98 cm, and WHR 0.85 ± 0.08, suggesting high frequency of visceral obesity, and increased risk of metabolic complications. However, when observed as WHtR ratio, visceral obesity was less pronounced: mean value was 0.57 ± 0.08, which is bellow the accepted limit of increased risk (0.62). In the overweight group, we found 90% of women with increased or substantially increased values of WC, but all subjects in this group were in the normal range of WHtR. In the obese group, we found that almost every woman had increased WC, but only one-third was in the range of increased metabolic risk when categorized according to WHtR. WC was significantly related to increased risk of hypertension even in young (22–30 years) student population in Serbia [14].

To date, the investigations were directed to obese or morbid obese men and women. Studies performed on overweight persons are sparse. Considering the frequency of overweight persons in our population, and the possibility of prediction the cardiovascular risk regardless of age and actual health status, we wanted to investigate this problem in particular.

The major characteristic of our results is significant difference observed between overweight and obese subjects in almost all important features. Besides the anthropometric differences which were expected (BW, BMI, %F), in the overweight group we recorded significantly lower values of parameters that reflect the metabolic risk: WC, WHR, WHtR, as well as significantly lower values of inflammatory marker CRP. CRP is a strong predictor of future vascular events, and the value obtained from initial blood sample may be useful in prediction even after twenty years [6]. When analyzed several large studies conducted both in Europe and the USA, the same author found the strong relationship between CRP concentrations and future cardiovascular events, apart from other risk factors. Prospective random study from MONICA project has processed large sample of initially health middle aged population and indicated the same strong relationship [5]. Moreover, the results from this study demonstrated that obese persons showed two-fold higher concentrations of CRP compared to persons with normal BMI. The importance of central obesity is confirmed in numerous studies, which proved stronger correlation of WC and WHR to higher cardiovascular risk, compared to BMI [14]. The role of visceral obesity is particularly important in persons with normal BMI.

The results from the Women's Health Study which enrolled 39,876 middle-aged women showed that women with CRP levels higher than 75th percentile (> 0.59 mg/dL) also had higher BMI, WC and WHR. After adjusting for age, CRP demonstrated strong correlation with BMI and W, but less strong correlation with WHR [15]. The results of our investigation confirmed the strong correlation between CRP levels and parameters of central adiposity in obese women, but also with BMI. This association is absent in overweight females.

A meta-analysis of 10 studies with a total of 88,514 subjects concluded that discriminatory power of markers of central obesity, such as WHtR, regarding cardiovascular risk is better than BMI, but this difference is small, insignificant, and with no clinical relevance [12]. Our results confirmed that WHtR significantly correlated with overall fat percentage, both in the overweight and obese group, but the correlation between WHtR and CRP was present only in the obese group.

The same pattern is observed for BAI. In this study we also estimated BAI as a new parameter of body adiposity,

which is very simple for use, since it does not require weight measurement. It is calculated from body height and hip circumference [11] and can be used to reflect overall fat (visceral and subcutaneous) percentage in both sexes and in different ethnicity. Although in mentioned large study conducted by Bergman et al. [11], BAI was defined as a strong predictor of fat percentage, our result showed significant correlation between these two parameters only in obese women, and not in overweight ones. In general, in the obese group we found that all anthropometric parameters and indices (BW, BMI, WC, WHR, WHtR and BAI) were significantly correlated to %F and hence reflect the overall adiposity.

Central obesity is strongly related to metabolic risk and has been identified as a useful predictor of metabolic syndrome. The link that connects visceral obesity to its metabolic complications may be systemic insulin resistance, however, the influence of adipose tissue on insulin sensitivity is not clear enough. Chronic inflammation is common characteristic of metabolic syndrome, particularly related to insulin resistance. On the other hand, infection and inflammation are also related to insulin resistance, while visceral obesity is related to chronic low-grade inflammation. Hence, these observations may introduce inflammation as a possible mechanism of effects of obesity on insulin resistance.

The proposed mechanism of induction of inflammation in obesity is increased secretory activity in adipose tissue. Adipose tissue is the site of production of numerous secretory factors (adipokines), with pro- and anti-inflammatory effects [16–18]. Homeostasis is maintained due to the balance in secretion of different factors. This homeostasis may be impaired in presence of adipose tissue enlargement, resulting in dysregulation of adipokine production, and following local and/or systemic inflammatory reaction [19]. Excessive fat tissue produces proinflammatory factors, particularly TNFα and IL-6, but also generates acute-phase reactants such as plasminogen activator inhibitor-1 (PAI-1), haptoglobin, serum amyloid A, which are the major contributors of low-grade systemic inflammation [20]. Obese persons seem to have increased activation of kinases in adipose tissue, and subsequently increased expression of inflammatory cytokines [21]. Levels of inflammatory cytokines in obese men and women are higher than in non-obese ones, and might be related to insulin resistance [22]. TNFα and other pro-inflammatory cytokines can contribute to inhibition of insulin receptor stubstrate-1 by inducing serine phosphorylation. Enlarged adipose tissue in humans also leads to infiltration of inflammatory immune cells and macrophages with substantial loss of functional programming, which may promote inflammation [23, 24].

These inflammatory mediators then induce synthesis of acute-phase reactants in liver, among them CRP, which is induced largely by IL-6. This results in increased serum concentration of these molecules even in healthy obese persons [25], including children [26]. These observations are in agreement with our results.

In order to explore this suggested association, Pannacciulli et al. [3] investigated CRP levels in apparently healthy women of different age (18–60 years), and with different nutritional status (normal weight, overweight, and obese) in relation to body composition and fat distribution. They found that CRP concentrations are correlated to fat mass, regardless of age, but visceral adiposity (measured by WC) was stronger predictor of CRP compared to overall fat mass. In addition, another study performed in 119 young (20–40 years) and healthy obese adults of both sexes showed that fat mass and fat percentage were predictors of CRP levels in a group of females under 30 years, but body composition did not predict CRP neither in older females, nor in males of any age [27].

Conclusion

In population of apparently healthy relatively young women, we found significant difference between the overweight and obese group in all parameters of central obesity, as well as in CRP levels. However, we recorded elevated concentrations of CRP even in overweight women. CRP levels were positively correlated to BMI, WC, WHR, WHtR, BAI and in the obese group, regardless of age, but in the overweight group no correlation was recorded. Finally, in the obese group, we found strong correlation between adiposity measured by fat percentage and parameters of central obesity, while in the overweight group WHR and BAI did not correlate to fat percentage. Our results confirmed that CRP is a valuable marker of metabolic risk in obese females, and BMI, although not so new, is still a reliable parameter of adiposity.

REFERENCES

1. *Stepien M, Stepien A, Wlazel RN, Paradowski M, Banach M, Rysz J.* Obesity indices and inflammatory markers in obese non-diabetic normo- and hypertensive patients: A comparative pilot study. Lipids Health Dis 2014; 13: 29−38.
2. *Stepien M, Stepien A, Wlazel RN, Paradowski M, Rizzo M, Banach M,* et al. Predictors of insulin resistance in patients with obesity: A pilot study. Angiology 2014; 65(1): 22−30.
3. *Pannacciulli N, Cantatore FP, Minenna A, Bellacicco M, Giorgino R, de Pergola G.* C-reactive protein is independently associated with total body fat, central fat, and insulin resistance in adult women. Int J Obes Relat Metab Disord 2001; 25(10): 1416−20.
4. *Jialal I, Devaraj S, Venugopal SK.* C-reactive protein: Risk marker or mediator in atherothrombosis?. Hypertension 2004; 44(1): 6−11.
5. *Koenig W, Sund M, Fröhlich M, Fischer HG, Löwel H, Döring A*, et al. C-Reactive protein, a sensitive marker of inflammation, predicts future risk of coronary heart disease in initially healthy middle-aged men: Results from the MONICA (Monitoring Trends and Determinants in Cardiovascular Disease) Augsburg Cohort Study. Circulation 1999; 99(2): 237−42.
6. *Ridker PM.* Clinical application of C-reactive protein for cardiovascular disease detection and prevention. Circulation 2003; 107(3): 363−9.

7. *Zeba AN, Delisle HF, Rosier C, Renier G.* Association of high-sensitive C-reactive protein with cardiomatabolic risk factors and micronutrient deficiencies in adults of Ougadougou, Burkina Faso. Br J Nutr 2013; 109(7): 1266−75.
8. *Sims EA.* Are there persons who are obese, but metabolically healthy?. Metabolism 2001; 50(12): 1499−504.
9. *World Healtj Organization.* Obesity: Preventing and managing the global epidemic. Geneva: World Health Organization; 2000.
10. *Durnin JV, Womersley J.* Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutr 1974; 32(1): 77−97.
11. *Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG*, et al. A better index of body adiposity. Obesity 2011; 19(5): 1083−9.
12. *Lee CM, Huxley RR, Wildman RP, Woodward M.* Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol 2008; 61(7): 646−53.
13. *Karastergiou K, Smith SR, Greenberg AS, Fried SK.* Sex differences in human adipose tissues - the biology of pear shape. Biol Sex Differ 2012; 3(1): 13.
14. *Stojanovic D, Visnjic A, Mitrovic V, Stojanovic M.* Risk factors for the occurrence of cardiovascular system diseases in students. Vojnosanit Pregl 2009; 66(6): 453−8. (Serbian)
15. *Balistreri CR, Caruso C, Candore G.* The role of adipose tissue and adipokines in obesity-related inflammatory diseases. Mediators Inflamm 2010; 2010: 802078.
16. *Rexrode KM, Pradahan A, Manson JE, Buring JE, Ridker PM.* Relationship of total and abdominal adiposity with CRP and IL-6 in women. Ann Epidemiol 2003; 13: 674−82.
17. *Leal Vde O, Mafra D.* Adipokines in obesity. Clin Chim Acta 2013; 419: 87−94.
18. *Coelho M, Oliveira T, Fernandes R.* Biochemistry of adipose tissue: an endocrine organ. Arch Med Sci 2013; 9(2): 191−200.
19. *Ouchi N, Parker JL, Lugus JJ, Walsh K.* Adipokines in inflammation and metabolic disease. Nat Rev Immunol 2011; 11(2): 85−97.
20. *Fuentes E, Fuentes F, Vilahur G, Badimon L, Palomo I.* Mechanisms of chronic state of inflammation as mediators that link obese adipose tissue and metabolic syndrome. Mediators Inflamm 2013; 2013: 136584.
21. *Rodriguez-Hernandez H, Simental-Mendia LE, Rodriguez-Ramirez G, Reyes-Romero MA.* Obesity and imflammation: Epidemiology, risk factors, and markers of inflammation. Int J Endocrinol 2013; 2013: 678159.
22. *Patel PS, Buras ED, Balasubramanyam A.* The role of immune system in obesity and insulin resistance. J Obes 2013; 2013: 616193.
23. *Han JM, Levings MK.* Immune regulation in obesity-associated adipose inflammation. J Immunol 2013; 191(2): 527−32.
24. *Bluher M.* Adipose tissue dysfunction contributes to obesity related metabolic diseases. Best Prac Res Clin Endocrinol Metab 2013; 27(2): 163−77.
25. *Berg AH, Scherer PE.* Adipose tissue, inflammation, and cardiovascular disease. Circ Res 2005; 96(9): 939−49.
26. *Visser M, Bouter LM, McQuillan GM, Were MH, Harris TB.* Low-grade systemic inflammation in overweight children. Pediatrics 2001; 107(1): E13.
27. *Forsythe LK, Livingstone MB, Barnes MS, Horigan G, Wallace JM.* C-reactive protein and body composition in a representative sample of young adults. Proceed Nutr Soc 2009; 67(OCE7): E267.

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