ORIGINAL ARTICLE

Comparison of Metabolic Syndrome Components, Inflammation and Oxidative Stress Indices in Normal Weight Obese and Normal Weight Women: A Case- Control Study

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Abstract

Background: Normal Body Mass Index (BMI)=18.5-24.9 kg/m^2 and high Body Fat (BF), have been defined as Normal Weigh Obesity (NWO), which can increase the risk of Metabolic Syndrome (MetS) and cardiovascular diseases. The present study aimed to determine the association between NWO and MetS indicators, Insulin Resistance (IR), and inflammatory and oxidative stress indices in NW obese compared to normal weight women referring to Imam Reza medical center, Shiraz, Iran.

Methods: In this case-control study, 41 healthy NW obese Iranian women were recruited and compared to 45 healthy non-obese control subjects. Anthropometric features, body composition, blood pressure, inflammation and oxidative stress indices, fasting insulin, lipid profile, and blood sugar were measured. IR was also assessed by means of special formulas.

Results: The results showed a significant difference between the NWO and the control group regarding anthropometric measurements and body composition, including waist (P=0.008) and hip (P<0.001) circumferences, BF (P<0.001), skeletal muscle (P=0.03), protein (P=0.04), body cell mass (P=0.02), bone mass content (P=0.04), and arm circumference (P<0.001). All subjects had normal systolic and diastolic blood pressures. However, the NWO group showed significantly higher serum concentrations of triglycerides (P=0.02), total cholesterol (P=0.02), and C-reactive protein (P<0.001). On the other hand, the results of McAuley test indicated significantly lower insulin sensitivity in the NWO group (P=0.03). Besides, serum MDA concentration did not have a marked differences in both study groups.

Conclusion: Comparison of body composition and anthropometric indices between NWO and normal weight women demonstrated that counting just on BMI to distinguish the individuals who are at risk of metabolic disorders might fail to identify a large number of individuals who, despite having a normal BMI, present excess BF and are at a high risk of metabolic imbalances.

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Introduction

Metabolic Syndrome (MetS) is characterized by a collection of metabolic conditions, including central obesity, glucose intolerance, dyslipidemia (high Triglyceride (TG) level and low High Density

Lipoprotein-Cholesterol (HDL-C) level), and hypertension (HTN). MetS increases the long-term risk of Cardiovascular Disease (CVD), Diabetes Mellitus (DM), and all-cause mortality.[1] A systematic review and meta-analysis reported that based on International Diabetes Federation (IDF) and Adult Treatment Panel III (ATP III) criteria, 34% and 30% of the Iranian population suffered from MetS, respectively. According to both criteria, the prevalence of the syndrome was higher among women compared to men.[2] Obesity has a negative effect on health and is strongly associated with MetS. Obese people are generally those whose Body Mass Index (BMI)is over 30 kg/m^2, while individuals with BMI >25kg/m^2 are considered to be overweight.[3] Despite its widespread clinical use, because of the limitations of BMI as a traditional diagnostic tool to differentiate between lean and body fat mass, this indicator has restricted the precision in diagnosing the individuals with excess Body Fat (BF) presenting BMI within the normal range.[4-6] In 2006, De Lorenzo et al.[7] among other authors,[8, 9] used the term 'Normal Weight Obesity' (NWO) to described a specific type of individuals who have high BF (above 30% in females and 23% in males), but normal body weight and BMI accompanied with total lean mass deficiency. Adipose tissue is not only specialized in the storage and mobilization of lipids, but it is also a remarkable endocrine organ releasing numerous cytokines.[10] A previous study showed that cardiovascular risk factors were related to metabolic variables and body fat mass distribution in normal weight obese women.[11] Some other studies have also reported associations between NWO and metabolic disorders.[7, 9] In a study performed on the US population, patients with NWO were four times more likely to develop MetS in comparison to those with normal BMI and BF.[9] Therefore, it seems that body fat is independently a stronger predictor than BMI for MetS and risk of CVD. However, to the best of our knowledge, there are few studies reporting an association between NWO and metabolic disorders in Iranian adult population. Such studies are important because if NWO is associated with metabolic imbalance, clinical evaluations must be changed and preventive public policy measures should be taken earlier in order to limit the complications of excess BF. Hence, the present study aims to determine the association between NWO and MetS indicators, Insulin Resistance (IR), and inflammatory and oxidative stress indices in normal weight obese compared to normal weight women referring to Imam Reza medical center, Shiraz, Iran.

Materials and Methods

Ethics Statement

The study protocol was approved by the Ethics Committee of Shiraz University of Medical Sciences. Indeed, all participants signed informed consent forms according to the guidelines of the Medical Ethics Committee.

Study Design and Participants

In this case-control study, conducted in the city of Shiraz, Iran, 41 healthy normal weight obese women aged 20-45 years with a BMI of 18.5-24.9 kg/m^2 and BF>30% were recruited from the Imam Reza Nutrition and Diet Therapy Clinic of Shiraz University of Medical Sciences; they were compared to 45 healthy non-obese control subjects (BMI=18.5-24.9 kg/m^2 and BF<25%). A sample size of 39 patients per group was determined based on the value of waist circumference (WC) of a previous study,[12] power of 90% and α=0.05. To allow for dropouts in each group, we determined 45 patients per group as the final sample size. The normal weight obese women were distinguished from the non-obese ones on the basis of their BF mass determined by Body Impedance Analysis (BIA), using the Fat Mass (FM) classification criterion. All women were in generally good health status, were free of any chronic diseases, had regular 28-day menstrual cycles, were not smokers or alcohol users, and did not take any hormonal contraceptives or other drugs. The participants were required to fill out a questionnaire containing information about their demographic and socioeconomic status (age, sex, occupation, education level, marital status, physical activity level, and family history of DM, HTN, and CVD).

Anthropometric and Body Composition Assessment

Anthropometric measurements were done by a trained nutritionist using a standard protocol.[13] Weight was measured to the nearest 0.1 kg using mechanical scales and height to the nearest 0.5 cm using a stadiometer while the subjects were wearing light clothes and no shoes. Subsequently, BMI was calculated as the ratio of weight/hight^2 (kg/m^2). In order to measure WC and Hip Circumference (HC), we used a flexible non-elastic tape. WC was measured at the end of a normal expiration as the smallest circumference between the ribs and the iliac crest while the participant was standing with the abdomen relaxed. HC was measured at the maximum circumference between the iliac crest and the crotch while the participant was standing following Lohman's protocol.[13] It should be noted that two measurements were recorded for waist and hip circumferences. In the case of observing variations >2cm in the recorded measurements, a third measurement was made. Waist-to-Hip Ratio (WHR) was calculated as well. To determine body components (BF, skeletal muscle, proteins, mineral, Fat Free Mass (FFM), Total Body Water (TBW), Extra-cellular Water (ECW), Intra-cellular Water (ICW), Body Cell Mass (BCM), Bone Mass Content (BMC), Arm Circumference (AC), Arm Muscle Circumference (AMC), Visceral Fat

Area (VFA), and Basal Metabolic Rate (BMR)), we used BIA in the post-absorptive state, injecting 800 micro ampere and 50-1000 kHz alternating sinusoidal current with a standard tetra polar technique (In Body S-10, USA). BIA was performed under standardized conditions, i.e. a quiet environment and ambient temperature of 22-24°C, after voiding and being at least 20 min at rest in seated position. No coffee or tea was drunk before the measurements as well.

Blood Pressure

Cuff arterial pressure was measured on the left arm by means of a mercury sphygmomanometer. In so doing, the participants were requested to have at least a 5-minute rest in seated position before Blood Pressure (BP) measurement. Systolic and diastolic pressures were recorded to the nearest 5 mmHg.

Biochemical Assessment

Five ml venous blood sample was drawn from all participants after a 12-hour fasting in a standardized manner by a trained technician. Then, the sera were separated and immediately frozen at -70 C until analysis. The sera were used for measurement of insulin, Fasting Blood Glucose (FBS), lipid profile (TG, total cholesterol, Low Density Lipoprotein-Cholesterol (LDL-C), and HDL-C), C- eactive protein (CRP), and Malondialdehyde (MDA). FBS (mg/dL), TG (mg/dL), and total and HDL cholesterol (mg/dL) were colorimetrically measured by a Biosystem A-25 auto-analyzer and the relevant commercial kits (Pars Azmoon, Tehran, Iran). LDL-C (mg/dL) was assessed via Friedewald calculation as follows:

LDL-C (mg/dL)=total cholesterol [mg/dL] – [HDL-C (mg/dL) – TG (mg/dL)/5]

It should be noted that the above formula could only be applied for the individuals whose fasting TG levels were below 400mg/dL.[14]

Fasting Insulin (FI) was measured by radioimmunoassay (insulin kit, DPC, Los Angeles, CA, USA) with the coefficient of variation=7.9%. Moreover, IR was assessed via six indirect methods, including FBS, FI, glucose/insulin ratio, HOMA-IR, QUICKI, and MacAuley tests. HOMA-IR, QUICKI, and MacAuleytests were done using the following formulae:[15]

HOMA=fasting insulin (μ U/mL) ×fasting glucose (mg/dL)/ 405, which was considered to be abnormal in case it was more than 2.

QUICKI=1/ (log insulin+log glucose in mg/dL), which was considered abnormal when ≤0.33.

MacAuley=exp [2.63-0.28 ln (insulin in mU/L)-0.31 ln (triglycerides in mmol/L)], with the abnormal values was considered to be ≤5.8 (8). However, FBS≥100, FI≥10, and glucose/insulin <4.5 were considered to be cut-off points in favor of IR. Moreover, the erum level of MDA was determined, using thiobarbituric acid reactive substances method on a spectrophotometer.

Statistical Analysis

Normal distribution of the data was assessed via one sample Kolmogorov-Smirnov test. Data processing and analysis were done using SPSS statistical software, version 21 for windows (SPSS Inc, Chicago, USA). All of the participants who completed an initial assessment were included in the final results analysis. Normally distributed data were expressed as mean±SD and compared by independent student's t-test. Pearson's correlation coefficient was applied to examine the relationships between the study variables. The significance level was set at <0.05.

Results

The mean age of the participants was 28.75±7.95 and 28.13±6.34 years in the NWO and control groups, respectively. The majority of the participants were single (57%) and 90.7% of them were highly educated (BA/BSc or higher degrees). Additionally, 36%, 36%, and 37.2% of the participants had a positive family history of DM, HTN and CVD, respectively.

The anthropometric characteristics of the study participants are presented in Table 1.

Table 1: Anthropometric characteristics and blood pressure of the participants in the NWO and control groups

	NWO (mean±SD)	Control (mean±SD)	P value‡
Number	41	45	
Age (year)	28.75±7.95	28.13±6.34	0.69
Height (cm)	160.29±6.60	162.48±5.53	0.09
Weight (kg)	58.62±5.77	55.62±7.41	0.03
BMI (kg/m2)	22.65±1.67	21.02±1.76	<0.001
WC (cm)	76.05±5.00	72.75±6.14	0.008
HC (cm)	99.46±4.51	95.64±4.57	<0.001
WHR	0.75±0.04	0.75±0.04	0.64
SBP (mmHg)	110.02±10.90	108.42±8.67	0.45
DBP (mmHg)	74.39±7.39	74.22±5.82	0.90

‡ Independent samples t-test; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist to hip ratio; SBP, systolic blood pressure, DBP, diastolic blood pressure

Accordingly, a significant difference was found between the two groups with respect to mean weight, BMI, WC, and HC. The two groups were also slightly different with regard to the mean height. On the other hand, all participants had normal systolic and diastolic BP.

As shown in Table 2, the two study groups were significantly different with respect to BF, skeletal muscle, protein, TBW, ECW, ICW, BCM, BMC, and AC.

Bases on the results, the NWO group showed a significantly higher TG, total cholesterol, and CRP serum concentrations than the control group. Other biochemical parameters including LDL-C, HDL-C, and FI were also higher in the NWO group although the differences were not statistically significant. Moreover, IR based on HOMA_IR was higher than the acceptable value in both study groups, but the difference was not statistically significant. However, based on McAuley test, insulin sensitivity was significantly lower in the NWO group. Besides, serum MDA concentration did not show a marked difference in both study groups (Table 3).

The results of Pearson's correlation coefficient revealed no statistically significant relationships between BF and MetS indices.

Discussion

In the present study, NWO was described as excess BF and normal BMI combined with abnormality in body composition and some metabolic imbalances. The results showed a significant difference between the NWO and control groups regarding anthropometric measures and

Table 2: BIA variables and derived estimates of body composition in the NWO and control groups

	NWO (mean±SD)	Control (mean±SD)	P value‡
Number	41	38	
Body fat (%)	34.19±2.74	23.31±2.16	<0.001
Skeletal muscle (%)	20.80±2.32	22.02±2.55	0.03
Protein (kg)	7.57±0.77	7.95±0.84	0.04
Mineral (kg)	2.75±0.29	2.87±0.28	0.05
FFM (kg)	38.53±3.88	39.39±7.10	0.50
TBW (%)	28.21±2.82	29.63±3.04	0.03
ECW (%)	10.70±1.05	11.21±1.10	0.03
ICW (%)	17.17±3.11	18.41±1.95	0.03
BCM (kg)	25.07±2.55	26.47±2.68	0.02
BMC (kg)	2.24±0.42	2.40±0.23	0.04
AC (cm)	28.67±1.54	26.94±1.99	0.00
(AMC (cm	21.93±1.02	21.77±1.61	0.60
(VFA (cm^2	77.51±10.40	49.45±13.10	0.001>
BMR (kcal/day)	1202.34±83.89	1244.42±90.00	0.03

‡ Independent samples t-test; FFM, fat free mass; TBW, total body water; ECW, extra cellular water; ICW, intra cellular water; BCM, body cell mass; BMC, bone mass content; AC, arm circumference; AMC, arm muscle circumference; VFA, visceral fat area; BMR, basal metabolic rate

Table 3: Biochemical parameters in the NWO and control groups

	NWO (mean±SD)	Control (mean±SD)	P value‡
Number	41	45	
FBS (mg/dL)	87.88±10.30	88.52±14.26	0.81
TG (mg/dL)	106.52±30.91	86.81±45.38	0.02
TC (mg/dL)	165.86±32.30	150.79±28.58	0.02
HDL-C (mg/dL)	54.39±11.13	54.63±8.91	0.91
LDL-C (mg/dL)	93.97±21.29	84.90±26.57	0.08
LDL-C/HDL-C	1.67±0.54	1.63±0.71	0.74
TC/HDL-C	3.11±0.59	2.86±0.90	0.14
CRP (pg/ml)	1061.34±192.48	855.35±381.65	0.00
MDA (mmol)	2.47±0.57	2.39±0.65	0.50
Insulin (m unit/l)	16.11±13.19	14.79±5.17	0.55
HOMA-IR	3.57±3.05	3.13±1.51	0.41
QUICKI	0.32±0.02	0.32±0.02	0.52
McAuley	6.46±1.22	7.08±1.36	0.03
FBS/insulin	6.82±3.55	6.62±3.54	0.80

‡ Independent samples t-test; FBS, fasting blood sugar; TG, triglyceride; TC, total cholesterol; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; CRP, C-reactive protein; MDA, malondialdehyde

body composition. Accordingly, NWO was associated with higher WC, HC, AC, and VFA and lower skeletal muscle, protein, mineral, BCM, and BMC. These results are in the same line with those obtained by Karkhaneh et al. which showed that anthropometric measurements including waist and hip circumference were higher in the NWO than in the non-NWO group.[12] Ascaso et al. also found that WC was a good indicator of the risk of IR and MetS, especially among non-obese subjects.[16] Similarly, Nurses' Health Study revealed that the women with WC> 76.2 cm were 1.8–2.3 times more likely to develop CVD in comparison to those with WC<71.1 cm. Besides, they showed that WC was strongly associated with increased risk of coronary heart disease among the women with BMI <25.0 kg/m^2.[17] In the present study, the mean of WC in the NWO group was 76.05±5.00 cm, which was near the cut-off value for WC in Nurses' Health Study. Hence, a larger number of participants in the NWO group might be at an increased risk of developing diabetes and coronary heart disease in future. Moreover, VFA was statistically higher in the NWO than in the control group. Lee et al. showed that not overall adiposity, but visceral fat seems to be related to increased cardiometabolic risk factors.[18] Kim et al. also concluded that VFA level was more important than WC, BMI, and liver fat in MetS at low obesity levels, while the liver fat was more important than visceral adiposity in overweight and obese individuals.[19] Adipose tissue that appears to be functionally comparable with a dynamic endocrine organ produces and secrets various adipokines, such as leptin, adiponectin, and proinflammatory factors like Tumor Necrosis Factor-α (TNF-α), Interleukin-6 (IL-6), and Interleukin-1 (IL-1), all of which play an important role in the onset of CVD, atherosclerotic processes, and IR.[10] Thus, it seems that excessive BF, especially along with visceral fat accumulation, had the potential to increase the risk of MetS in the NWO group in the current study. This might be attributed to the generation of the majority of circulating FFAs, abnormal adipokines secretion, and the subsequent inflammatory status.[10]

Although the results indicated no significant differences between the two groups regarding some biochemical characteristics, serum concentrations of CRP, TG, and total cholesterol were significantly higher in the NWO group. These results were in line with the previously published data.[7, 12] A meta-analysis of seven prospective studies also demonstrated that elevated levels of CRP, as a sensitive marker for systemic inflammation in the acute phase, could predict the future risk of coronary heart disease.[20] In the same vein, some other studies reported that elevated levels of CRP were associated with increased WC and hyperglycemia,[21] IR[22] and BMI,[23] which eventually increased the number of MetS components. The present study results, together with the evidence obtained in the previous studies, suggest the onset of a state of low-grade systematic inflammation combined with excess BF in NWO, which is quite notable and must be seriously intentioned to be reduced.

Another finding of the current study was the higher TG level in the NWO group. Hypertriglyceridemia in the presence of IR is the result of both an increase in Very Low Density Lipoprotein (VLDL) production and a decrease in VLDL clearance because of the role of insulin in regulation of lipoprotein lipase enzyme, a major mediator of VLDL clearance. Besides, impaired insulin signaling increases the lipolysis, resulting in increased FFA levels in the liver. It should be mentioned that FFAs serve as a substrate for TG synthesis. FFAs also stabilize the production of apo B, resulting in higher VLDL production.[10]

In the current study, young adult women with NWO showed a higher concentration of fasting insulin in comparison to those without NWO although the difference was not statistically significant. NWO was also associated with increased IR and low insulin sensitivity measured by the McAuley model. The reduced sensitivity to insulin has been detected among the subjects with NWO in previous studies as well.[12, 24, 25] The higher insulin secretion in these subjects is possibly a compensatory response to the reduced insulin sensitivity found in individuals with NWO.

In this study, the participants' serum MDA was measured as a marker of Systemic Oxidative Stress (SOS), but its mean levels o showed no significant differences between the groups. MDA, the main product of polyunsaturated fatty acid peroxidation is an extremely toxic substance. Some recent studies demonstrated that, in non-diabetic human subjects, fat accumulation closely correlated with the markers of SOS, suggesting that oxidative stress correlates with BMI, and eventually SOS in the accumulated fat mediates the obesity-associated development of MetS.[26]

There are few limitations to the present study, including the rather small sample size that led to a decrease in the power of calculations and correlation analyses. Besides, the study data had better be adjusted for socioeconomic status, dietary intake, and other lifestyle variables such as physical activity and smoking status to get more precise results. Indeed, more accurate methods, such as Dual-energy X-ray Absorptiometry (DXA) and CT scan, are recommended to be used for measurement of body composition in future studies. Finally, this study was conducted on the participants with NWO compared to non-obese women. Thus, further studies are suggested to compare the individuals with NWO to those considered obese base on BMI. It seems that along with the a universal high-BMI obesity epidemic,[27] there is a worldwide normal-BMI obesity that usually begins at younger ages.

Conclusion

In summary, comparison of body composition and anthropometric indices between NWO and normal weight women indicated that focusing just on BMI to distinguish the individuals who are at risk of metabolic disorders may fail to identify a great number of individuals who, despite having a normal BMI, present excess BF and are at a high risk of metabolic imbalance. Therefore, physicians are recommended to explore metabolic abnormalities in individuals with normal weight and those at the lower end of the overweight spectrum since early detection of those with NWO may be profitable in prevention of diabetes and CVD. Moreover, the current weight-loss recommendations do not advise losing weight for patients with normal BMI, while it seems that individuals with normal BMI but high BF would likely benefit from weight loss, improved dietary intakes, and physical activity programs.

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References

1 Grundy SM, Brewer HB, Jr., Cleeman JI, Smith SC, Jr., Lenfant C. Definition of metabolic syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. Circulation. 2004;109 (3):433-8.

2 Dalvand S, Bakhshi E, Zarei M, Asl MT, Ghanei R. Prevalence of Metabolic Syndrome in Iran: A systematic review and meta-analysis. Medical-Surgical Nursing Journal. 2017;5 (4):1-14.

3 Han TS, Lean ME. A clinical perspective of obesity, metabolic syndrome and cardiovascular disease. JRSM cardiovascular disease. 2016;5:2048004016633371.

4 Collazo-Clavell M, Lopez-Jimenez F. Accuracy of body mass index to diagnose obesity in the US adult population. International Journal of Obesity. 2008;32 (6):959-66.

5 Okorodudu D, Jumean M, Montori V, Romero-Corral A, Somers V, Erwin P, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis. International journal of obesity. 2010;34 (5):791.

6 De Lorenzo A, Bianchi A, Maroni P, Iannarelli A, Di Daniele N, Iacopino L, et al. Adiposity rather than BMI determines metabolic risk. International journal of cardiology. 2013;166 (1):111-7.

7 De Lorenzo A, Martinoli R, Vaia F, Di Renzo L. Normal weight obese (NWO) women: an evaluation of a candidate new syndrome. Nutrition, Metabolism and Cardiovascular Diseases. 2006;16 (8):513-23.

8 Marques-Vidal P, Pécoud A, Hayoz D, Paccaud F, Mooser V, Waeber G, et al. Prevalence of normal weight obesity in Switzerland: effect of various definitions. European journal of nutrition. 2008;47 (5):251.

9 Romero-Corral A, Somers VK, Sierra-Johnson J, Korenfeld Y, Boarin S, Korinek J, et al. Normal weight obesity: a risk factor for cardiometabolic dysregulation and cardiovascular mortality. European heart journal. 2009;31 (6):737-46.

10 de Ferranti S, Mozaffarian D. The perfect storm: obesity, adipocyte dysfunction, and metabolic consequences. Clinical chemistry. 2008;54 (6):945-55.

11 De Lorenzo A, Del Gobbo V, Premrov MG, Bigioni M, Galvano F, Di Renzo L. Normal-weight obese syndrome: early inflammation?–. The American journal of clinical nutrition. 2007;85 (1):40-5.

12 Karkhaneh M, Taheri E, Qorbani M, Mohajeri Tehrani MR, Hoseini S. ASSESSMENT OF METABOLIC SYNDROME COMPONENTS IN OBESE WOMEN WITH NORMALWEIGHT COMPARED TO NON OBESE HEALTHY WOMEN. Iranian Journal of Diabetes and Metabolism. 2015;14 (4):279-86.

13 Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual: Human kinetics books Champaign; 1988.

14 Kannan S, Mahadevan S, Ramji B, Jayapaul M, Kumaravel V. LDL-cholesterol: Friedewald calculated versus direct measurement-study from a large Indian laboratory database. Indian journal of endocrinology and metabolism. 2014;18 (4):502.

15 Jahromi BN, Dabaghmanesh MH, Parsanezhad ME, Fatehpoor F. Association of leptin and insulin resistance in PCOS: A case-controlled study. International Journal of Reproductive BioMedicine. 2017;15 (7):423.

16 Ascaso JF, Romero P, Real JT, Lorente RI, Martínez-Valls J, Carmena R. Abdominal obesity, insulin resistance, and metabolic syndrome in a southern European population. European Journal of Internal Medicine. 2003;14 (2):101-6.

17 Rexrode KM, Carey VJ, Hennekens CH, Walters EE, Colditz GA, Stampfer MJ, et al. Abdominal adiposity and coronary heart disease in women. Jama. 1998;280 (21):1843-8.

18 Lee J, Chung D-S, Kang J-H, Yu B-Y. Comparison of visceral fat and liver fat as risk factors of metabolic syndrome. Journal of Korean medical science. 2012;27 (2):184-9.

19 Faria G, Gonçalves A, Cunha R, Guimaraes J, Calhau C, Preto J, et al. Beyond central adiposity: liver fat and visceral fat area are associated with metabolic syndrome in morbidly obese patients. International Journal of Surgery. 2015;14:75-9.

20 Danesh J, Collins R, Appleby P, Peto R. Association of fibrinogen, C-reactive protein, albumin, or leukocyte count with coronary heart disease: meta-analyses of prospective studies. Jama. 1998;279 (18):1477-82.

21 González AS, Guerrero DB, Soto MB, Díaz SP, Martinez-Olmos M, Vidal O. Metabolic syndrome, insulin resistance and the inflammation markers C-reactive protein and ferritin. European journal of clinical nutrition. 2006;60 (6):802.

22 Deepa R, Velmurugan K, Arvind K, Sivaram P, Sientay C, Uday S, et al. Serum levels of interleukin 6, C-reactive protein, vascular cell adhesion molecule 1, and monocyte chemotactic protein 1 in relation to insulin resistance and glucose intolerance—the Chennai Urban Rural Epidemiology Study (CURES). Metabolism. 2006;55 (9):1232-8.

23 Guldiken S, Demir M, Arikan E, Turgut B, Azcan S, Gerenli M, et al. The levels of circulating markers of atherosclerosis and inflammation in subjects with different degrees of body mass index: soluble CD40 ligand and high-sensitivity C-reactive protein. Thrombosis research. 2007;119 (1):79-84.

24 Karelis AD, St-Pierre DH, Conus F, Rabasa-Lhoret R, Poehlman ET. Metabolic and body composition factors in subgroups of obesity: what do we know? The Journal of Clinical Endocrinology & Metabolism. 2004;89 (6):2569-75.

25 Madeira FB, Silva AA, Veloso HF, Goldani MZ, Kac G, Cardoso VC, et al. Normal weight obesity is associated with metabolic syndrome and insulin resistance in young adults from a middle-income country. PloS one. 2013;8 (3):e60673.

26 Furukawa S, Fujita T, Shimabukuro M, Iwaki M, Yamada Y, Nakajima Y, et al. Increased oxidative stress in obesity and its impact on metabolic syndrome. The Journal of clinical investigation. 2017;114 (12):1752-61.

27 Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. Jama. 2012;307 (5):491-7.