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Interrelationship between serum lipid profile, serum hormones and other components of the metabolic syndrome

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The aim of the present study was to investigate the association between the serum lipid profile and components of the metabolic syndrome, such as central obesity (anthropometric, computed tomography and fat cell data), insulin, sex-hormone-binding-globulin (SHBG) and different hormones influencing this important syndrome, e.g. sex steroids, leptin and tumor necrosis factor-alpha (TNF-α). The sample consisted of 85 obese patients (30 men and 55 women) who had undergone abdominal surgery. Fasting serum lipids were analysed, as well as anthropometric and computed tomography data, perivisceral and subcutaneous fat cell size and serum glucose and hormones. Abdominal fat revealed itself as an important correlator of the adverse changes in plasma lipoprotein levels, the waist-to-hip-ratio and waist-to-thigh-ratio being the best morphological correlators in men and women, respectively. Intra-abdominal fat (VA) correlated significantly and positively to perivisceral fat cell size in women, while no correlation was found between subcutaneous fat accumulation (SA) and adipocyte size in both genders. Perivisceral fat cell size showed the greatest number of correlations with the adverse plasma lipid profile compared to that in the subcutaneous depot. SHBG and sex steroids showed a negative correlation with serum lipids considered a cardiovascular risk. In contrast, TNF-α and C-peptide were inversely correlated with potential protector lipids. In conclusion, abdominal obesity, adipocyte hypertrophy from visceral fat, serum TNF-α and C-peptide seem to be the best correlators of the lipoprotein disturbance characteristic of the metabolic syndrome, whereas SHBG and sex steroids could play a protective role regarding the lipid profile associated to this syndrome.

Keywords: Serum lipids, SHBG, Metabolic syndrome, Fat cell size, Visceral obesity.

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Several studies have pointed to a relationship between abdominal obesity and cardiovascular diseases, partially mediated through an altered plasma lipid metabolism (12, 22, 23). Hypertriglyceridemia and low high-density lipoprotein cholesterol (HDL-C) concentration constitute the major lipid alterations observed in obesity (12, 23). A large segment of the adult population of industrialised countries develops metabolic syndrome as a result of genetic, hormonal and lifestyle factors such as obesity, physical inactivity and certain nutrient excesses. This syndrome is now usually considered to consist of insulin resistance, visceral obesity, high circulating concentrations of triglycerides and triglyceride-rich very low density lipoprotein particles, low concentrations of high density lipoprotein particles as well as hypertension (25).

Because so many risk factors are interrelated in this disease, it is difficult to isolate the effect of a specific risk factor on the lipid profile, making this an exciting and challenging area for research. Visceral fat has been proposed as the most important fat depot related to an unfavourable serum lipid profile and it has also been described as an important link between the many facets of the metabolic syndrome (2). However, this view has been challenged by ABATE *et al.*, (1) and GOODPASTER *et al.*, (11) who found that abdominal subcutaneous fat, determined by computed tomography, was at least as influential in the metabolic syndrome as visceral fat.

In addition, it has been emphasised that the endocrine abnormalities described in obesity, which involve steroid hormones and insulin, may actually result in abdominal depot fat accumulation (10). This fact might contribute to the metabolic syndrome in susceptible individuals, but there is conflicting information about the particular relationship between the different hormones and the serum lipid profile (5, 13, 28).

This article examines the association between serum lipid profile and different components of the metabolic syndrome, such as central obesity (anthropometric measurements, computed tomography and fat cell data), and serum hormones that could influence some aspects of this important syndrome: insulin, sex hormone binding globulin (SHBG), sex steroids, leptin and tumor necrosis factor-alpha (TNF-α).

Subjects and Methods

Subjects.– Eighty-five patients, which included men (n = 30) and pre- (n = 21) and post-menopausal women (n = 34), aged between 30 and 70, were selected from the outpatient clinics of the University "Virgen de la Arrixaca", the General University and the "Morales Meseguer" hospitals in Murcia, Spain. All patients were obese with a body mass index (BMI) of 27-35 kg/m^2, and were admitted for abdominal surgery or laparoscopy for gallbladder disease without icterus, ulcer or umbilical hernia. Patients who were on a special diet, who were under treatment with thermogenic, lipogenic or contraceptive drugs, or who had a diagnosis of diabetes mellitus, chronic renal failure, hepatic diseases or cancer were excluded from the study. Informed consent was required for the study, which was approved by the Ethics Committee of the "Virgen de la Arrixaca" Hospital.

Anthropometric and computed tomography measurements.– With patients in their underwear, body weight was measured to the nearest 0.1 kg, and height was

measured to the nearest centimetre. From this data, the BMI was calculated. Total body fat (%) was derived from skinfold measurements taken from the bicep, tricep, suprailiac and subscapular regions (8). All measurements were obtained from the right side, with the subject upright and relaxed, using a Harpenden caliper (Holtain Ltd, Bryberian, Crymmych, Pembrokeshire, UK) with a constant pressure of 10 g/mm^2. Body fat distribution was assessed by measuring waist circumference at the level of the umbilicus, hip circumference over the widest part of the greater trocanters, and oblique thigh. All these measurements were carried out three times by a single operator. The waist-to-hip ratio (WHR), waist-to-thigh ratio (WTR) and conicity index (CI) (36) were calculated. Measurements of visceral and subcutaneous adipose tissue areas were performed by computed tomography (CT) scan, according to Sjöstrom (30) using a TOSHIBA CBTB007A Scanner (Toshiba corporation 1385-1, Shimoshiqui, Otowawara, Japan). A single 10 mm scan at L4 - L5 level determined to the nearest 1 mm by a skeleton radiogram was performed with a 512 x 512 matrix, a window size of 300 Hounsfield units (HU) and a centre of 40 HU. The subcutaneous (SA) and visceral abdominal fat areas (VA) were determined from a tomodiagram section by image analysis using a MIP-Microm Image Processing System (Microm, Barcelona, Spain) based on the IMCO 10 (Kontron, Eching, Germany) and the VA/SA index was calculated (33).

Plasma lipids.– Blood samples were collected the day before surgery following an overnight fast. Plasma triglycerides, total cholesterol (TC), high density lipoprotein and low density lipoprotein cholesterol (HDL-C, LDL-C), apoproteins A-1 and B (apo A and B) were determined in a venous blood sample by immunoturbidimetric assay with commercial kits from Roche diagnostics GmbH (Mannheim, Germany).

Plasma hormones.– Insulin, TNF-α and SHBG were determined by IRMA with reagents from Biosource (Fleurus, Belgium), Medgenix diagnostics (Fleurus, Belgium) and Orion Diagnostica (Espoo, Finland), respectively. The sensitivity of the method was 1 µIU/ml for insulin, 5 pg/ml for TNF-α and 0.5 nmol/l for SHBG. The intra-assay coefficient of variation (CV) was 4.5% at a serum insulin concentration of 6.6 µIU/ml and 2.1% at 53 µIU/ml; 6% at a serum TNF-α concentration of 67.4 pg/ml and 2.2% at 1328.0 pg/ml; and 5.3% at a serum SHBG concentration of 17.7 nmol/l and 5.6% at 156.8 nmol/l. 17β-estradiol and testosterone were determined by ELISA/competition with biotine/estreptavidine technology with reagents purchased from Boehringer Mannheim Immunodiagnostics (Meylan, France). Androstenedione, leptin, C-peptide and DHEA-S were determined by RIA with reagents purchased, respectively, from Immunonotech (Marseille, France), Linco Research (St. Charles, MO, USA), Byk-Santeg Diagnostica, DSL (von Hevesy-Strasse, Dietzenbag) and Diagnostic Systems Laboratories Inc. (Webster, TX, USA). The assay had sensivities of 0.1 ng/ml for androstenedione, 0.5 ng/ml for leptin, 0.05 ng/ml for C-peptide and 1.7 µg/dl for DHEA-S. The intra-assay coefficients of variation (CV) were 8.9% at a mean androstenedione concentration of 0.58 ng/ml and 4.1% at a mean value of 6.68 ng/ml; 8.3% at a mean leptin concentration of 4.9 ng/ml and 3.4% at 25.6 ng/ml;

4.8% at a mean C-peptide value 0.76 ng/ml and 2.9% at 12.53 ng/ml, 9.4% at a mean DHEA-S concentration of 20.3 µg/dl and 6.3% at 593.3 µg/dl. The normal range according to the hospital standards were the following: Insulin: 5-25 µIU/mL; C-peptide: 0.3-2.5 ng/ml; Leptin: 7.5 ± 9.3 ng/ml; TNF-α: 0-20 pg/m; 17β-estradiol: 10-39 pg/ml in males and 10-147 pg/ml in females in the folicular phase, 110-338 pg/ml during menses, 27-247 pg/ml in the luteal phase and 0.01-46 pg/ml in postmenopausal state; Androstenedione: 0.61-3.71 ng/ml males and 0.46-3.39 ng/ml females; Testosterone: 2-8.5 ng/dl males and 0.01-0.86 ng/dl females; DHEA-S: 281-606 mg/dl males from 17 to 50 years, 117-342 µg/dl males > 50 years, 195-507 µg/dl females, 7-348 µg/dl postmenopausal state; SHBG: 10-50 nM males, and 30-90 nM females.

Adipose tissue examinations.– Abdominal adipose tissue samples were obtained during surgery. Subcutaneous samples were taken from the periumbilical region, and intra-abdominal samples from perivisceral fat surrounding the gallbladder. Samples were stored in Ringer solution at –70 °C until just before analysis. Adipocyte sizes of different regions were determined according to Sjöstrom et al. (29). All measurements were conducted by the same operator. Intra-operator variability was examined from duplicate measurements of the same slice from several subjects (n = 7), in two different slices from the same adipose tissue sample, and in slices observed by different operators. The correlation factors were 0.99, 0.99 and 0.94, respectively.

Statistical analyses.– The comparisons between different population groups (men, premenopausal and postmenopausal women) were analysed by means of one way ANOVA. Pearson's correlation coefficients were used to quantify the relations between the serum lipid profile and the different components of the metabolic syndrome. $P < 0.05$ was considered significant. Data were analysed with BMDP4M statistical software (4).

Results

Fasting triglycerides, TC, LDL-C, HDL-C, apo A and B from the obese population studied are shown in Table I. Men showed significantly higher serum lipids than postmenopausal women except for HDL-C values that were significantly lower. Premenopausal women displayed the least atherogenic serum profile.

Table II represents the different variables that could define the metabolic syndrome, including central obesity (anthropometric, computed tomography and fat cell data), plasma levels of glucose, insulin, SHBG, leptin, TNF-α and sex hormones (17β-estradiol, testosterone, androstenedione and DHEA-S). Important gender differences were found as well as between pre- and post-menopausal status in body fat content, body fat distribution and in every serum hormone analysed except for androstenedione. No statistically differences were found in fat cell size among the different groups.

Tables III and IV show significant correlations (r) between plasma lipids and the different components of the metabolic syndrome for men and women, respectively. Pearson's correlation procedures indicate that abdominal distribution factors associated with cardiovascular risk plasma lipids were different between men and women, the WHR being the most closely related in the former and the WTR in the latter. In women, VA was correlat-

Table I. *General characteristic and serum lipids of the studied population.*

Parameter	Men (n = 30)	Postmenopausal women (n = 34)	Premenopausal women (n = 21)	P value*
Age (years)	56 ± 15[b]	61 ± 6[c]	38 ± 8	0.000
Weight (kg)	87.7 ± 13.9[a]	73.6 ± 9.1[c]	83.9 ± 10.9	0.000
Height (m)	1.66 ± 0.09[d]	1.50 ± 0.04	1.58 ± 0.06	0.000
Triglycerides (mmol/l)	2.09 ± 1.18	1.79 ± 0.77	1.67 ± 0.65	0.249
Cholesterol (mmol/l)	4.94 ± 1.12[a]	6.03 ± 1.19[c]	5.17 ± 1.17	0.001
HDL-C (mmol/l)	1.08 ± 0.38[a]	1.35 ± 0.41	1.3 ± 0.36	0.037
LDL-C (mmol/l)	3.04 ± 0.88[a]	4.91 ± 0.91[c]	2.93 ± 0.83	0.037
Apo A (g/l)	1.15 ± 0.30[a]	1.50 ± 0.56	1.32 ± 0.38	0.020
Apo B (g/l)	0.98 ± 0.30	1.23 ± 0.40	1.06 ± 0.37	0.060

Data are expressed as mean ± s.d. *ANOVA was used for comparisons among groups. Significant differences between: [a]Men and postmenopausal women; [b]men and premenopausal women; [c]postmenopausal and premenopausal women; [d]three population groups, $P < 0.05$.

Table II. *Different metabolic syndrome components as central obesity (anthropometric, computed tomography and fat cell data) plasma glucose and serum hormones.*

Metabolic Syndrome components	Men (n = 30)	Postmenopausal women (n = 34)	Premenopausal women (n = 21)	P value*
BMI (Kg/m^2)	31.4 ± 2.9	32.5 ± 3.5	33.6 ± 4.5	0.111
Body fat (%)	24.7 ± 4.6[d]	33.3 ± 6.3	37.3 ± 7.3	0.000
Waist (cm)	110.4 ± 10.5	108.9 ± 8.7	107.9 ± 15.2	0.720
Hip (cm)	106.4 ± 10.3[b]	108.3 ± 1.2[c]	115.2 ± 10.9	0.004
Thigh (cm)	65.6 ± 3.3[b]	65.6 ± 1.5[c]	72.3 ± 7.8	0.005
WHR	1.04 ± 0.10[b]	1.00 ± 0.07[c]	0.93 ± 0.07	0.000
WTR	1.73 ± 0.20[b]	1.68 ± 0.21[c]	1.51 ± 0.16	0.004
Conicity index	1.40 ± 0.07	1.43 ± 0.08[c]	1.35 ± 0.12	0.019
Sagittal (cm)	25.6 ± 6.0	26.1 ± 2.4	26.3 ± 3.1	0.814
Visceral area (cm^2)	199.9 ± 76.6[b]	166.8 ± 82.7[c]	115.4 ± 50.1	0.000
Subcutaneous area (cm^2)	226.3 ± 92.2[d]	337.8 ± 91.4	397.0 ± 114.2	0.000
VA/SA	0.96 ± 0.35[d]	0.54 ± 0.38	0.32 ± 0.18	0.000
Glucose (mg/dl)	124.1 ± 69.2	103.4 ± 34.8	123.8 ± 67.0	0.284
17 β-estradiol (pmol/l)	82.9 ± 57.2[b]	54.7 ± 65.7[c]	280.0 ± 228.3	0.000
Testosterone (nmol/l)	12.50 ± 4.58[ab]	0.87 ± 0.83	0.90 ± 0.93	0.000
DHEA-S (µmol/l)	4119 ± 4173[a]	1870 ± 1599	3387 ± 2303	0.000
SHBG (nmol/l)	34.5 ± 22.1[ab]	55.6 ± 27.4	61.0 ± 48.5	0.010
Androstenedione (nmol/l)	5.40 ± 2.97	4.40 ± 2.31	5.82 ± 3.01	0.178
Insulin (nmol/l)	94.7 ± 62.4[b]	101.8 ± 54.5[c]	148.5 ± 81.1	0.010
C-peptide (nmol/l)	1.20 ± 0.72	1.11 ± 0.48	1.42 ± 0.79	0.234
TNF-α (pg/ml)	19.3 ± 9.1[a]	24.7 ± 8.6	20.5 ± 6.3	0.033
Leptin (ng/ml)	8.2 ± 3.9[ab]	30.0 ± 14.3	25.1 ± 13.2	0.000
Subcutaneous fat cell size (µg)	0.46 ± 0.15	0.52 ± 0.18	0.48 ± 0.13	0.521
Perivisceral fat cell size (µg)	0.52 ± 0.24	0.46 ± 0.17	0.43 ± 0.11	0.458

Data are expressed as mean ± s.d. *ANOVA was used for comparisons among groups. Significant differences between groups as in Table I. BMI: Body mass index; WHR: Waist and hip ratio; WTR: Waist and thigh ratio; VA/SA: Visceral and subcutaneous areas ratio. DHEA-S: Dehydroepiandrosterone-sulfate.

ed with an increase in LDL-C, and (VA/SA) with an increase in plasma total cholesterol. A regression analysis between the different plasma lipids and hormones shows that SHBG and most steroids were negatively correlated with cardiovascular risk lipids (LDL-C, apo B, TG and TC). DHEA-S was correlated with a decreased level of LDL-C in the total population studied ($P < 0.05$; $r = -0.25$). TNF-α and C-peptide were negatively correlated with the potential protector lipids: HDL-C and apo A. When women were divided depending on the menopausal status (pre- and post-menopausal) most of the significant correlations disappeared (data not shown).

A highly significant correlation was seen between serum lipids and fat cell size from abdominal adipose tissue in the different groups (Tables III and IV): Pearson's correlation procedures indicated that, in men, perivisceral fat cell size was significantly and positively correlated with triglycerides, TC, apo B and LDL-C ($r = 0.84$, $P < 0.05$; $r = 0.85$, $P < 0.05$; $r = 0.95$, $P < 0.001$; $r = 0.81$, $P < 0.05$) while in postmenopausal women, perivisceral fat

Table III. *Significant correlations between plasma lipids and the different components of the metabolic syndrome for men.*

Men	Triglycerides	Cholesterol	HDL-C	LDL-C	Apo A	Apo B
WHR	NS	0.44[1,a]	NS	0.43[a]	NS	0.43[a]
Conicity index	NS	NS	-0.38[a]	NS	NS	NS
17 β-estradiol	NS	-0.50[a]	NS	-0.51[a]	NS	-0.56[b]
Testosterone	-0.61[b]	-0.54[a]	NS	-0.38[a]	NS	-0.45[a]
SHBG	-0.46[a]	-0.46[a]	NS	NS	NS	NS
Perivisceral fat cell size	0.84[a]	0.85[a]	NS	0.81[a]	NS	0.95[c]

[1]r values, NS = not significant.
[a]$P < 0.05$; [b]$P < 0.01$, [c]$P < 0.001$. Pearson correlation test.

Table IV. *Significant correlations between plasma lipids and the different components of the metabolic syndrome for women.*

Women	Triglycerides	Cholesterol	HDL-C	LDL-C	Apo A	Apo B
Hip	NS	-0.27[1,a]	NS	-0.31[a]	NS	NS
WHR	0.35[a]	NS	NS	NS	NS	NS
WTR	0.33[a]	0.33[a]	NS	0.37[a]	NS	0.44[b]
Visceral area (VA)	NS	NS	NS	0.36[a]	NS	NS
VA/SA	NS	0.32[a]	NS	0.47[b]	NS	NS
17 β-estradiol	NS	-0.27[a]	NS	-0.33[a]	NS	NS
Testosterone	NS	-0.29[a]	NS	NS	NS	NS
Androstenedione	NS	NS	NS	-0.32[a]	NS	NS
C-peptide	NS	NS	-0.30[a]	NS	-0.34[a]	NS
TNF-α	0.27[a]	NS	NS	NS	NS	NS
Perivisceral fat cell size (Prem.)	NS	NS	NS	NS	NS	0.62[c]
Subcutaneous fat cell size (Postm.)	NS	NS	NS	NS	- 0.69[a]	NS

[1]r values, NS = not significant. Prem.= Premenopausal; Postm. = Postmenopausal women.
[a]$P < 0.05$; [b]$P < 0.01$, [c]$P < 0.001$. Pearson correlation test.

cell size was positively associated with apo B (r = 0.62, P < 0.001). In premenopausal women, no significant association were found with perivisceral fat cell size and serum lipids, however, subcutaneous fat cell size was inversely correlated with apo A in this group of women (r = -0.69, P < 0.05). It is important to note the significant positive relation between perivisceral adipocyte size and the accumulation of intra-abdominal fat (AV) in women (r = 0.55, P < 0.05) while no significant relationship was seen in men. No significant correlation was found between subcutaneous fat cell size and subcutaneous fat accumulation (SA) in both sexes.

Discussion

The metabolic syndrome has been defined as a manifestation of two or more of these components: Fasting serum level of glucose ≥ 7.0 mmol/l; fasting serum level of triglycerides ≥ 1.7 ml/l or HDL-C < 1.0 mmol/l or both and central obesity (waist-to-hip ratio > 0.85 or BMI ≥ 30 kg/m^2 or both) (23) (18). Following these criteria the population studied shows clear signs of metabolic syndrome.

Data indicate that abdominal fat was an important correlator of the adverse changes in plasma lipoprotein levels observed in the metabolic syndrome. Visceral obesity (VA and VA/SA) was a significant correlator of plasma LDL-C and total cholesterol levels among obese women. However among men, WHR seemed to be a better predictor of cardiovascular risk than VA, contrary to other studies that suggest a very poor predictive value for this index (22, 24). It has been postulated that although WHR is a poor measurement of intra-abdominal fat mass, the statistical power of this index is greater than might be expected and it seems likely that it contains additional information to intra-abdominal fat mass, perhaps a muscle component included in the hip circumference measurement (32). In women the best morphological correlator of altered plasma lipoprotein was the WTR. TERRY *et al*, (35) have reported similar results, suggesting a potentially protective role of thigh fat. Contrary to ABATE *et al.* (1) and TAI *et al.* (18), and in accordance with classical studies (7, 21), subcutaneous fat accumulation does not seem to be an important component in the metabolic syndrome in regards to the serum lipid profile.

When the female population was divided into pre- and post-menopausal women, most of these significant correlations disappeared. The fact that the female population included in each group was very homogeneous, with a narrow range of values in anthropometric parameters, could partly explain these results.

Of both adipose tissue regions studied, the fat cell size in the perivisceral region showed the greatest correlation with the adverse plasma lipid profile. In men, fat cell size from this adipose area seems to present a higher cardiovascular risk than the total fat content from this fat depot (VA). The absence of significant correlations between VA and serum lipid disturbances in men might be because in this gender, increased VA was not associated with an increase in adipocyte size. In contrast, in women the amount of visceral fat was positively associated with perivisceral fat cell size, which, in turn, was associated with an increase in apo B. This fact, together with the absence of a significant correlation between subcutaneous fat cell size and subcutaneous fat accumulation (SA), might indicate that the metabolic disturbance associated with visceral fat is mainly due to hypertrophy of the

adipocyte in this fat depot. There is no evidence to confirm that fat cell hypertrophy is associated with a primary malfunction of the adipocyte in relation to plasma lipids. However, it is possible that an excess of triglycerides may produce changes in fat cell metabolism and that these may be responsible for many of the metabolic alterations associated with human obesity. Several authors have observed that hyperinsulinemia, insulin resistance and hypertriglyceridemia (metabolic syndrome) is associated with hypertrophy of fat cells (9). Whatever the case, adipocyte size plays a role (still to be fully understood in lipid metabolism) in its relation with body fat distribution and with different metabolic syndrome components.

The results obtained after regression analysis of the different plasma hormones and lipids point to the positive effect of sex steroids on lipid metabolism. The beneficial effects of 17 β-estradiol on circulating LDL-C levels in women has been widely demonstrated. Before menopause, women have a lesser cardiovascular risk than men but the rapid postmenopausal increase in LDL-C levels means that the opposite becomes true (20), a finding borne out by our study. 17 β-estradiol also seems to have a beneficial effect in men, being shown that plasma levels of this hormone were negatively associated with LDL-C levels (27). These results coincide with ours since we, too, found a negative correlation between a circulating 17 β-estradiol levels and plasma levels of total cholesterol, LDL-C and apo B.

Testosterone was associated with a drop in triglyceride, total cholesterol, LDL-C and apo B levels. This possible cardioprotective role has not been clearly established, although some authors (14) indicated that high testosterone levels in men are associated with lower abdominal fat accumulation and increased HDL-C levels. However, other results (28) found no association between cardiovascular risk factors and plasma testosterone levels, concluding that intervention studies need to be performed before the administration of androgens can be recommended for the prevention or treatment of cardiovascular diseases.

There is also conflicting information about the influence of testosterone on plasma lipid levels in women. It has been previously shown that a relative hyperandrogenicity in women is associated with a powerful risk of developing type 2 diabetes mellitus, cardiovascular diseases, hypertension and endometrial cancer followed by premature mortality (5). However, some studies have claimed that testosterone in women acts as a protector against cardiovascular risk (6, 26) which coincides with our present findings.

Dehydroepiandrosterone-sulfate (DHEA-S) was negatively associated with LDL-C levels in the total population studied. Similar studies, in which the plasma level of this hormone and of different lipids were determined, also pointed to a negative association between DHEA-S and LDL-C (20).

In agreement with the results of other studies (17, 34), SHBG, a plasma glycoprotein with high binding affinity for testosterone and dihydrotestosterone and a lower affinity for 17β-estradiol, is negatively correlated with triglycerides and total cholesterol, suggesting that decreased SHBG levels may be one of the components of metabolic syndrome.

In the present population leptin was significantly and positively correlated with BMI, total body fat (kg), and fat cell size, as has been previously published by our group (10). However, simple regres-

sion analysis did not identify relationships between plasma leptin and serum lipids, coinciding with many studies in patients with combined hyperlipidemy as well as in healthy control subjects (15, 16).

TNF-α was correlated with increased triglyceride levels while C-peptide was correlated with diminished HDL-C and apo A. It has been suggested that TNF-α and other cytokines *in vivo* induce hypertriglyceridemia in 45 minutes (31). It seems, then, that TNF-α does not delay triglyceride clearing but, on the contrary, activates hepatic lipogenesis, increasing the concentration of citrate (allosteric activator of acetyl CoA carboxylase) and the VLDL-C production.

In summary, abdominal obesity, hypertrophy of perivisceral adipocytes, plasma TNF-α and C-peptide concentrations correlate with the adverse lipid profile that characterises metabolic syndrome. In contrast, serum SHBG and sex steroids might have beneficial effects on the serum lipid profile and, as a consequence, could play a protective role against this syndrome. Subcutaneous fat does not seem to be an important component in the metabolic syndrome as regard to the lipid profile.

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M. GARAULET, F. PÉREZ-LLAMAS, S. ZAMORA AND F. J. TEBAR. *Interrelaciones entre el perfil lipídico del plasma y las hormonas plasmáticas y otros componentes del síndrome metabólico.* J. Physiol. Biochem., **58** (3), 151-160, 2002.

Se investiga la asociación entre el perfil lipídico del plasma y algunos componentes del síndrome metabólico, tales como la obesidad central, y los niveles de insulina, proteína transportadora de hormonas sexuales (SHBG), esteroides sexuales, leptina y factor de necrosis tumoral alfa TNFα. La muestra incluye 85 pacientes obesos (30 hombres y 55 mujeres) sometidos a cirugía abdominal. Analizados los lípidos plasmáticos en ayunas, datos antropométricos y de tomografía computerizada, tamaño del adipocito en grasa subcutánea y perivisceral y los valores plasmáticos de glucosa y hormonas, se observa correlación entre grasa abdominal y alteraciones de los valores plasmáticos de lipoproteínas, siendo los índices cintura-cadera y cintura-muslo los parámetros morfológicos que mejor correlación presenta en hombres y mujeres, respectivamente. La grasa intraabdominal (VA) se correlaciona significativa y positivamente con el tamaño del adipocito perivisceral en mujeres, mientras que no se encuentra correlación entre el tamaño adipocitario y la grasa subcutánea (SA) para ningún género. El tamaño adipocitario perivisceral presenta mayor número de correlaciones con el perfil lipídico desfavorable del plasma, comparado con el subcutáneo. Los esteroides sexuales y SHBG se correlacionan negativamente con los lípidos plasmáticos considerados de riesgo cardiovascular. Por el contrario, el péptido C y el TNFα lo hacen con lípidos potencialmente protectores. En conclusión, la obesidad abdominal y la hipertrofia de los adipocitos de la grasa visceral, junto con el péptido C y el TNFα plasmáticos se asocian positivamente con la alteración de las lipoproteínas característica del síndrome metabólico, mientras que los esteroides sexuales y SHBG parecen desempeñar un papel protector respecto del perfil lipídico.

Palabras clave: Lípidos plasmáticos, SHBG, Síndrome metabólico, Tamaño de adipocito, Obesidad visceral.

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