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## Original

# Study and classification of the abdominal adiposity throughout the application of the two-dimensional predictive equation Garaulet et al., in the clinical practice

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**Abstract**

***Introduction:*** **The excess of visceral abdominal adipose tissue is one of the major concerns in obesity and its clinical treatment.**

***Objective:*** **To apply the two-dimensional predictive equation proposed by Garaulet *et al.* to determine the abdominal fat distribution and to compare the results with the body composition obtained by multi-frequency bioelectrical impedance analysis (M-BIA).**

***Subjects/methods:*** **We studied 230 women, who underwent anthropometry and M-BIA. The predictive equation was applied. Multivariate lineal and partial correlation analyses were performed with control for BMI and % body fat, using SPSS 15.0 with statistical significance $P < 0.05$.**

***Results:*** **Overall, women were considered as having subcutaneous distribution of abdominal fat. Truncal fat, regional fat and muscular mass were negatively associated with $VA/SA_{predicted}$, while the visceral index obtained by M-BIA was positively correlated with $VA/SA_{predicted}$.**

***Discussion/Conclusion:*** **The predictive equation may be useful in the clinical practice to obtain an accurate, costless and safe classification of abdominal obesity.**

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Key words: *Abdominal obesity. Visceral adipose tissue. Multi-frequency bioelectrical impedance analysis. Anthropometry. Truncal fat.*

**ESTUDIO Y CLASIFICACIÓN DE LA ADIPOSIDAD ABDOMINAL MEDIANTE LA APLICACIÓN DE LA ECUACIÓN PREDICTIVA BIDIMENSIONAL DE GARAULET ET AL., EN LA PRÁCTICA CLÍNICA**

**Resumen**

***Introducción:*** **El exceso de tejido adiposo abdominal visceral es una de las mayores preocupaciones en la obesidad y su tratamiento clínico.**

***Objetivo:*** **Aplicar la ecuación predictiva bidimensional propuesta por Garaulet et al., para determinar la distribución de la grasa abdominal y comparar los resultados con la composición corporal obtenida mediante el análisis de impedancia bioeléctrica multi-frecuencia (M-BIA).**

***Sujetos/métodos:*** **Estudiamos a 230 mujeres a las que se sometió a antropometría y M-BIA. Se aplicó la ecuación predicitiva. Se realizaron correlaciones lineales multivariadas y parciales controlando el IMC y el % de grasa corporal, utilizando SPSS 15.0 con significación estadística $P < 0,05$.**

***Resultados:*** **En global, se consideró que las mujeres tenían una distribución subcutánea de la grasa abdominal. La grasa troncal, regional y la masa muscular se asociaron negativamente con $VA/SA_{predicha}$, mientras que le índice visceral obtenido mediante M-BIA se correlacionó positivamente con $VA/SA_{predicha}$.**

***Discusión/conclusión:*** **La ecuación predictiva puede ser útil en la práctica clínica para obtener una clasificación segura, barata y precisa de la obesidad abdominal.**

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Palabras clave: *Obesidad abdominal. Tejido adiposo visceral. Análisis por impedancia bioeléctrica de multifrecuencia. Antropometría. Grasa troncal.*

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## Introduction

One the major concerns in the clinical treatment of obesity is the excess of adipose tissue located in the abdominal region and it´s increased associated risk. The visceral adipose tissue (VAT) is considered the clinically relevant type of body fat independently of total body fat,[1] closely linked with increased risk of type 2 diabetes and cardiovascular disease.[2]

Imaging techniques as magnetic resonance imaging (RMI) or computed tomography (CT)[3] ensure an accurate quantification of abdominal fat compartments, but their economic cost and complexity make them not suitable in the clinical practice or in large-scale studies. Although several anthropometric measures have been validated as indicators of VAT or SAT compartments,[4] no single parameters are considered as accurate measures of both fat deposits.[5] Also, it has been suggested that one-dimensional variables are not complete models for estimating two-dimensional parameters such as cross-sectional fat areas,[6] that have been described as ellipses rather than circles, even in obese subjects.[7] Based on this fact, Garaulet et al. have developed a two-dimensional equation,[8] based on the elliptical model, using the classical ratio of visceral area (VA) over subcutaneous area (SA) at the umbilicus level. This equation was validated in obese subjects who underwent computed tomography and anthropometry and was established a cut-off point at the level of 0.42. The classical VA/SA ratio has been used as a diagnostic criterion for classifying obesity into subcutaneous and visceral types[9] and has shown important associations with metabolic disturbances.[10]

Bioelectrical Impedance analysis (BIA) is a popular alternative to assess body composition because is a safe, non-invasive and portable method. Modern multi-frequency BIA (M-BIA) technology also includes the ability to provide total body fatness and regional estimates such as truncal fatness.[11] Recent studies have shown good agreement between M-BIA and dual-energy X-ray absorptiometry (DXA) for estimating changes in body composition during weight loss in overweight young women.[12] However, M-BIA may not be widely available in the clinical practice.

The purpose of the present study was to apply a two-dimensional predictive equation proposed by Garaulet et al.[8] to determine the abdominal fat distribution in women included in a cognitive-behavioral therapy for the treatment of obesity,[13] and to compare the results with the body composition obtained by M-BIA, with the purpose to reach a more accurate, costless and easier classification of the abdominal obesity in the clinical practice mainly based in the application of the predictive equation.

## Subjects and methods

### *Subjects*

The studied population was composed by 230 women, aged 39 ± 12 years, with BMI 29 ± 5 and % body fat 35.4 ± 5.3, who visited the "Garaulet Nutritional Centers", in Murcia, Spain, and were included in a cognitive-behavioral therapy based on the Mediterranean diet for the treatment of obesity.[13] The Ethics Committee of the University of Murcia approved this study and the informed consent was obtained before the experiments.

### *Anthropometric measurements*

According to SEEDO 2007 Consensus,[14] body weight was measured by a clinical scale with 100 g recess, and body height was measured with a Harpender digital stadiometer (0.7-2.05 m range), in barefooted subjects. BMI was calculated as weight (kilograms) divided by squared height (meters). Body fat distribution was assessed using the waist circumference (WC) at the level of the umbilicus; hip circumference (HC) over the widest part of the greater trocanters; sagittal diameter was measured at the level of the iliac crest (L4-5) using a Holtain Kahn Abdominal Caliper,[15] as the distance between the examination table up to the horizontal level, allowing the caliper arm to touch the abdomen slightly but without compression;[16] and coronal diameter was measured at the level of iliac crest (L4-5), with the patient lying in a supine position in the examination table. The abdominal caliper was perpendicular to the body.[15] The waist to hip ratio (WHR) was also calculated.[17] Skinfold thicknesses (biceps, triceps, subscapular and suprailiac) were measured with a Harpender calliper (Holtain Ltd., Bryberian, Crymmych, Pembrokeshire), on the right side of the body with the subject standing up in a relaxed position. The complete set of anthropometric measurements was performed three times but not consecutively, and were obtained in order and repeated a second and a third time. All these measurements were carried out by the same person. To analyze the abdominal fat distribution, the two-dimensional predictive equation proposed by Garaulet et al.,[8] was calculated with the following formula:

Visceral area (VA)/Subcutaneous area (SA) predicted = 0.868 + (0.064 x sagittal diameter) – (0.036 x coronal diameter) – (0.022 x triceps skinfold).

According to the values obtained by the predictive equation in the present study, we classified individuals into subcutaneous and visceral group using the cut-off point proposed by Garaulet et al. who have classified visceral obese subjects as those individuals with $VA/SA_{predicted} \geq 0.42$.

### *Multi-frequency bioelectric impedance analysis (M-BIA)*

To guarantee the maximum accuracy of the data, all the measurements were performed in bare-footed and fasting individuals. These measures were obtained by TANITA MC-180 (TANITA Corporation of America, Inc, Arlington Heights, IL, USA), equipped with 8 tactile electrodes: a platform with 2 electrodes for each foot and two handgrips with two electrodes each. We obtained total body measures, excluding the head, such as total body fat (% and kg), muscular mass (kg), fat free mass (kg), total body water (kg); and the regional measures were truncal fat (kg), visceral index, muscular truncal mass (kg), fat leg mass (kg), fat arm mass (kg), muscular leg mass (kg) and muscular arm mass (kg). The visceral index obtained by M-BIA has been previously validated through Computed Tomography and DXA in both spinal-cord injured and healthy patients respectively.

### *Statistical analysis*

Data are expressed as mean ± s.e.d. Statistical differences between means were tested using multivariate lineal analyses controlled for BMI and total body fat (%). Partial correlation coefficients controlled for BMI and total body fat (%) were performed to determine the relations between general characteristics, anthropometrical variables and M-BIA data, with $VA/SA_{predicted}$ by the two-dimensional equation. All statistical procedures were performed using SPSS 15.0 for Windows (SPSS Inc., Chicago, USA). Statistical significance was defined with $P$ values < 0.05.

## Results

### *General characteristics, anthropometry and multi-frequency bioelectric impedance data*

Clinical and M-BIA data from the total population are presented in Table 1. The studied population presented overweight (BMI = 29 ± 5). The mean value of $VA/SA_{predicted}$ classified females with subcutaneous distribution. Women had mean values of total body fat (%) considered as obesity.[14]

### *Classification of individuals according to the $VA/SA_{predicted}$*

To classify the total population into subcutaneous or visceral abdominal distribution we used the cut-off point proposed by Garaulet et al. (table I). The subcutaneous group presented significantly higher values of weight, coronal diameter, skinfold thicknesses, fat free mass, total body water, truncal fat (% respect to total fat), muscular truncal and leg mass. The visceral group presented significant higher values of sagittal diameter. The visceral index obtained by M-BIA was not significantly different between groups, but it was slightly higher in the visceral group.

### *Associations between $VA/SA_{predicted}$ and the variables derived from anthropometry and M-BIA analysis*

Table II shows the partial correlation coefficients between anthropometric and M-BIA measures and $VA/SA_{predicted}$ values. Regarding the anthropometric variables, hip circumferences (HC) ($P < 0.05$), coronal diameter ($P < 0.001$) and skinfold thicknesses ($P < 0.001$) were significantly and negatively correlated with the predictive equation values. Whereas, sagittal diameter correlated positively. We also observed significant and negative correlations between the equation values and fat free mass, total body water, truncal fat ($P < 0.01$) and muscular truncal ($P < 0.05$) and leg mass ($P < 0.01$). The predictive equation was significantly and positively associated with the visceral index obtained by M-BIA ($P < 0.001$).

## Discussion

The present study was designed to show the effectiveness of the two-dimensional predictive equation in the classification of the abdominal obesity in the clinical practice. It has been stated that no single clinical anthropometric measure correlates well with visceral adipose tissue (VAT) in the prediction of the abdominal fat depot.[11] The equation published by Garaulet et al., is composed by coronal and sagittal diameters plus triceps skinfold, having the advantage that can measure two-dimensional variables as cross-sectional areas like VAT.[6] Those three variables were revealed as strong and significant contributors to the explained variance of VA/SA obtained by computed tomography (CT) by multiple regression analysis.[8] This equation showed more accuracy than previous models such as the circular model, the elliptical model using different abdominal and back skinfolds,[7] and even more than the classical visceral obesity classification proposed by Tarui et al.[9]

In the studied population, women presented overweight and had waist circumference and waist-to-hip ratio (WHR) slightly greater than the accepted highly risk cut-off points.[14] Taking into account these variables, women presented little risk of metabolic disturbances associated with obesity.[18] The application of the predictive equation revealed that, overall, women were considered as having a subcutaneous distribution of the abdominal fat. After statistical control for BMI and total body fat (%), a positive correlation between the $VA/SA_{predicted}$ and the visceral index (VI) obtained by M-BIA was found. Considering the VI as an indicator of visceral obesity, we can assume that the equation is classifying the patients adequately. Measures of visceral adiposity through M-BIA have shown important correlations with visceral area determined by CT and DXAThe VI has been validated throughout CT in both healthy individuals and patients with spinal cord injury,[19] and even stronger correlations than the waist circumference.[19,20]

**Table I**

*General characteristics, anthropometric and multi-frequency bioelectric impedance data in the total population and differences between means classifying women according to $VA/SA_{predicted}$*

| | *Total population n = 230* | *Subcutaneous group $VA/SA_{predicted} \leq 0.42$ (n = 164)* | *Visceral group $VA/SA_{predicted} > 0.42$ (n = 66)* | *p* |
|---|---|---|---|---|
| Weight (kg) | 75 ± 13 | 75.56 ± 0.45 | 73.39 ± 0.72 | 0.013 |
| Waist (cm) | 91.54 ± 11.08 | 91.66 ± 0.46 | 90.62 ± 0.75 | 0.248 |
| Hip (cm) | 106.89 ± 10.06 | 107.33 ± 0.54 | 105.45 ± 0.87 | 0.073 |
| WHR | 0.86 ± 0.08 | 0.86 ± 0.01 | 0.86 ± 0.01 | 0.699 |
| Coronal diameter (cm) | 33.74 ± 4.40 | 34.52 ± 0.22 | 31.63 ± 0.36 | 0.000 |
| Sagittal diameter (cm) | 20.92 ± 3.01 | 20.71 ± 0.12 | 21.21 ± 0.20 | 0.039 |
| Biceps skinfold (mm) | 15.75 ± 7.48 | 16.49 ± 0.44 | 13.05 ± 0.71 | 0.000 |
| Triceps skinfold (mm) | 30.30 ± 8.01 | 32.59 ± 0.40 | 23.75 ± 0.65 | 0.000 |
| Subscapular skinfold (mm) | 29.15 ± 9.87 | 30.01 ± 0.59 | 26.31 ± 0.95 | 0.001 |
| Suprailiac skinfold (mm) | 31.47 ± 9.56 | 32.42 ± 0.62 | 28.98 ± 1.01 | 0.005 |
| $VA/SA_{predicted}$ | 0.33 ± 0.19 | 0.23 ± 0.01 | 0.56 ± 0.02 | 0.000 |
| Visceral Index | 6,29 ± 2,87 | 6.20 ± 0.12 | 6.59 ± 0.20 | 0.110 |
| Total Body Fat (kg) | 26.73 ± 8.45 | 26.79 ± 0.20 | 26.43 ± 0.33 | 0.367 |
| Muscular mass (kg) | 45.17 ± 6.79 | 45.47 ± 0.37 | 44.08 ± 0.61 | 0.058 |
| Fat free mass (kg) | 47.40 ± 6.20 | 47.69 ± 0.31 | 46.25 ± 0.49 | 0.016 |
| Total body water (kg) | 33.91 ± 4.47 | 34.11 ± 0.22 | 33.08 ± 0.36 | 0.017 |
| Truncal fat (kg) | 12.60 ± 4.31 | 12.80 ± 0.13 | 12.32 ± 0.21 | 0.057 |
| Truncal fat (% respect to total fat) | 46.39 ± 7.54 | 47.50 ± 0.29 | 46.38 ± 0.46 | 0.046 |
| Fat leg mass (kg) | 5.52 ± 1.60 | 5.49 ± 0.04 | 5.54 ± 0.06 | 0.553 |
| Fat arm mass (kg) | 1.52 ± 0.68 | 1.52 ± 0.02 | 1.51 ± 0.03 | 0.816 |
| Muscular truncal mass (kg) | 26.13 ± 3.56 | 26.27 ± 0.17 | 25.46 ± 0.28 | 0.016 |
| Muscular leg mass (kg) | 7.31 ± 0.97 | 7.38 ± 0.06 | 7.12 ± 0.09 | 0.020 |
| Muscular arm mass (kg) | 2.17 ± 0.32 | 2.19 ± 0.02 | 2.13 ± 0.03 | 0.105 |

Data are presented as mean ± s.e.d. BMI: body mass index, WHR: waist to hip ratio. VA: visceral area, SA: subcutaneous area. Bold characters indicate significant differences between groups with P ≤ 0.05. Multivariate lineal analysis was controlled for BMI (body mass index) and total body fat (%).

The partial correlation analysis also revealed negative correlations between $VA/SA_{predicted}$ and truncal fat, regional fat and muscular mass. These results support the fact that women tend to gain more subcutaneous fat in the abdominal region. This observation is consistent with others that states that premenopausal[20] premenopausal[21] and postmenopausal[22] women have more abdominal subcutaneous adipose tissue than men.

The utilization of the predictive equation proposed by Garaulet et al. (2006) may have some advantages over M-BIA, especially if modern equipments of M-BIA are not available in the daily practice. However, some limitations may be taken into account. One of the key issues is how the triceps skinfold, a negative component of the equation, affects the values of $VA/SA_{predicted}$. Our results showed that the visceral group ($VA/SA_{predicted} \geq 0.42$) had significantly less weight and truncal fat (% respect to total fat) than the subcutaneous group. These results could be explained by significantly fewer values of triceps in the women classified as visceral group compared with those classified in the subcutaneous group (Table 2). This skinfold has been shown to be highly correlated to total body fat in different population groups[22,23] groups,[23,24] and was correlated to subcutaneous fat in the previous study of Garaulet et al.[8] In this case, the triceps skinfold is diving women according to the % of body fat. On the other hand, the predictive equation was validated in obese women, while women in the present study presented overweight, although both population had a wide range of BMI and % total body fat. To avoid the influence of obesity degree, the statistical analyses were controlled for both variables.

In summary, the predictive equation proposed by Garaulet et al. (2006) has satisfactorily classified overweight women with a subcutaneous distribution of the abdominal fat, and the results showed good agreement with the visceral index and other variables derived from M-BIA. The predictive equation is useful in the clinical practice and can be applied without any other method or equipment to obtain an accurate, costless and safe classification of the obese patients.

**Table II**
*Partical correlation coefficients for the independent association between VA/SA predicted and total body composition*

| | Total population |
|---|---|
| Waist (cm) | NS |
| Hip (cm) | -0.135* |
| WHR | NS |
| Coronal diameter (cm) | -0.515‡ |
| Sagittal diameter (cm) | 0.258‡ |
| Biceps skinfold (mm) | -0.316‡ |
| Triceps skinfold (mm) | -0.723‡ |
| Subscapular skinfold (mm) | -0.209† |
| Suprailiac skinfold (mm) | -0.159* |
| Total Body Fat (kg) | NS |
| Muscular mass (kg) | NS |
| Fat free mass (kg) | -0.181† |
| Total body water (%) | -0.197† |
| Truncal fat (kg) | -0.183† |
| Truncal fat (% respect to total fat) | -0.151* |
| Visceral Index | 0.246‡ |
| Fat leg mass (kg) | NS |
| Fat arm mass (kg) | NS |
| Muscular truncal mass (kg) | -0.161* |
| Muscular leg mass (kg) | -0.171† |
| Muscular arm mass (kg) | NS |

WHR: waist to hip ratio. Partial correlation analysis was controlled for BMI and total body fat (%). *$p < 0.05$; †$p < 0.01$; ‡$p < 0.001$. NS: not significant.

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