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# The estimation of visceral adipose tissue with a body composition monitor predicts the metabolic syndrome

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## Abstract

**Background:** Central obesity has a higher risk of the metabolic syndrome (MetS) and cardiovascular diseases. It is estimated by measuring waist circumference (WC) and waist-to-hip ratio (WHR), which are operator-dependent. The present study aimed to validate a body composition monitor (BCM) as a tool for estimating visceral adipose tissue (VAT), as well as to assess its capacity to predict the MetS and its correlation with anthropometric parameters.
**Methods:** We measured WC, WHR and body mass index (BMI) in 60 recruited subjects. BCM estimated VAT (1–30 points). Body composition and resting energy expenditure (REE) were compared with bioelectrical impedance analysis (BIA) and indirect calorimetry, respectively. VAT was estimated by BCM (range 1–30 points), We evaluated the capability of VAT, WC, BMI and WHR to predict the MetS by ATP-III criteria.
**Results:** The mean (SD) age of subjects was 36.8 (12.9) years, 80% were female, and 47% had the MetS. Body composition and REE estimated by BCM had a significant correlation with BIA ($r$ = 0.85–0.91, $P$< 0.001) and REE ($r$ = 0.86, $P$ < 0.001), respectively, even after adjusting by sex. VAT estimation by BCM was positively correlated with WC ($r$ = 0.75, $P$< 0.001) and WHR ($r$ = 0.61, $P$ < 0.001). The area under the receiver operator characteristic curves to predict the MetS was 0.93 for VAT, 0.81 for WC, 0.76 for WHR and 0.74 for BMI. VAT $\geq$10 points had a sensitivity of 100% and a specificity of 82% for predicting the MetS.
**Conclusions:** VAT estimation by BCM efficiently predicts the MetS and correlates with anthropometric parameters of central obesity. Its routine use could facilitate cardiovascular risk estimation and follow-up in overweight and obese patients in ambulatory practice.

## Introduction

Central obesity is associated with the metabolic syndrome (MetS), diabetes, hypertension and dyslipidaemia (Wang *et al.*, 2005; Bray *et al.*, 2008), and is estimated by waist circumference (WC) or waist-to-hip ratio (WHR) (Dervaux *et al.*, 2008; Gelber *et al.*, 2008; Winter *et al.*, 2008). Both increased WC and WHR have been associated with higher cardiovascular risk, although they have inter-operator and inter-measurement variability (Medina & Kaempffer, 2005; Dervaux *et al.*, 2008; Gelber *et al.*, 2008).

In clinical practice, body composition can be evaluated using bioelectrical impedance analysis (BIA), which

RB and JMD contributed equally to the present study.

estimates total body adipose tissue (Kyle *et al.*, 2004; Sun *et al.*, 2005). Nevertheless, BIA does not routinely estimate visceral adipose tissue (VAT) (Kyle *et al.*, 2004; Sun *et al.*, 2005), which can be measured by computed tomography (CT) or magnetic resonance, requiring additional evaluations and costs (Lee & Gallagher, 2008).

A low cost body composition monitor (BCM) can also estimate both fat and lean mass by bioimpedanciometry, and quickly estimates VAT and resting energy expenditure (REE) in ambulatory practice.

The present study aimed to validate a particular BCM as a tool to study body composition and REE. It also aimed to evaluate the estimation of VAT by BCM as a predictor of the MetS, as well as its correlation with anthropometric and biochemical parameters.

## Materials and methods

### Patients

Sixty adult subjects (48 females and 12 males) were consecutively recruited in a 6-month period from an Overweight and Obesity Clinic. We excluded subjects who were older than 80 years, weighing $\geq$140 kg, pacemaker or implantable defibrillators users and pregnant women.

Body composition was evaluated with a Single Frequency Bio-impedance Analyser BodyStat 1500 (Bodystat Ltd, Douglas, Isle of Man, UK) and REE was measured with an indirect calorimeter (Deltatrac MBM-100; Datex Instrumentarium Corp, Helsinki, Finland).

We evaluated body composition and estimated VAT with the OMRON® HBF 500 BCM (Omron Corp., Kyoto, Japan), in accordance with the formula developed by the manufacturer (range 1–30 points that represent a calculated score, not $cm^2$) on dressed subjects after a 12 h of fasting.

Because the present study was performed in a clinical practice-based environment, we were able to collect blood samples from 38 (28 females and 10 males) out of 60 patients. Fasting glucose and lipid profile were measured (Roche, Tokyo, Japan). Subjects were classified as having the MetS if they had at least three out of five variables, according to modified NCEP-ATP-III criteria (Grundy, 2007).

The present study was approved by our Institutional Review Board.

### Statistical analysis

Data values were compared using the Mann–Whitney test and correlations were performed using Spearman's correlation test. We studied the capacity of VAT, WC and BMI to predict the MetS with receiver operator characteristic (ROC) curves. Because our sample was enriched for female subjects, we performed linear regression analysis adjusted by sex and compared the partial correlation coefficient with the unadjusted correlation coefficient. Considering sensitivity and specificity, we determined the best value of VAT to predict the MetS. $P < 0.05$ (two-tailed) was considered statistically significant.

## Results

A total of 60 patients met the inclusion criteria [age 36.8 (12.9) years, weight 88.6 (19) kg, BMI 33.9 (6.1) kg $m^{-2}$, median VAT 10 (range 18–71)]; 48/60 (80%) were female.

Body composition evaluation was strongly correlated when measured by the BCM and BIA: fat mass weight, $r = 0.97$, $P < 0.001$; fat mass percentage, $r = 0.86$, $P < 0.001$; lean mass percentage, $r = 0.85$, $P < 0.001$ (Fig. 1).

The REE measured by BCM was strongly correlated with the indirect calorimetry measurement ($r = 0.87$, $P < 0.001$). All the correlations maintained significance when adjusted by sex.

Visceral adipose tissue (VAT) was positively correlated with WC ($r = 0.75$, $P < 0.001$) and WHR ($r = 0.61$, $P < 0.001$) (Figs 2 and 3).

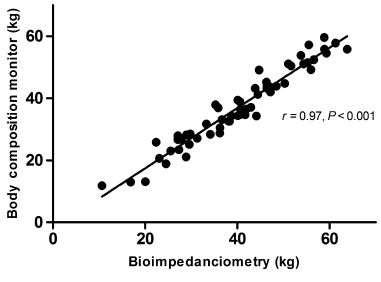


**Figure 1** Correlation of fat mass weight measured by bioimpedanciometry and body composition monitor.

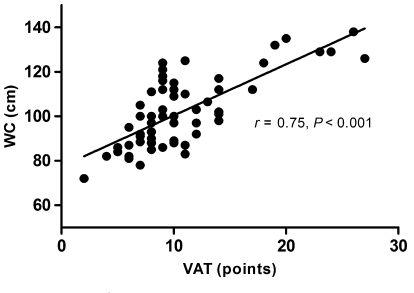


**Figure 2** Correlation of visceral adipose tissue estimation and waist circumference ($n = 38$). VAT, visceral adipose tissue; WC, waist circumference.

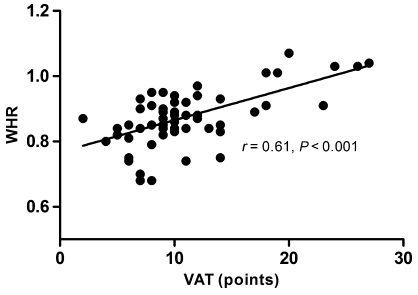


**Figure 3** Correlation of visceral adipose tissue estimation and waist-to-hip ratio ($n$ = 38). VAT, visceral adipose tissue; WHR, waist-to-hip ratio.

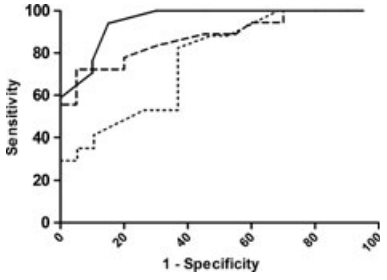


**Figure 4** Receiver operator characteristic curves for estimation of visceral adipose tissue estimation, waist circumference and waist to hip ratio to diagnose metabolic syndrome ($n$ = 38). VAT, visceral adipose tissue; WC, waist circumference; WHR, waist-to-hip ratio.

The MetS was diagnosed in 47% (18/38) (11 females and seven males) and these had significantly higher WC, BMI, triglycerides and fasting glucose than patients without the MetS (Table 1). Subjects with the MetS had a higher VAT estimation: median of 14 points (range 9–27) versus 7 points (range 2–12) ($P < 0.001$] (Table 1).

The area under the ROC curves for predicting the MetS was 0.93 [95% confidence interval (CI) = 0.89–1.01] for VAT, 0.81 (95% CI = 0.74–0.99) for WC, 0.76 (95% CI = 0.60–0.91) for WHR and 0.74 (95% CI = 0.67–0.95) for BMI (Fig. 4). VAT $\geq$ 10 points had a sensitivity of 100% and a specificity of 82% for predicting the MetS, correctly classifying 94.1% of true cases of the MetS in our study cohort.

## Discussion

The present study shows that VAT estimation by a low cost BCM has a good capacity for predicting the MetS and a strong correlation with anthropometric parameters that evaluate central obesity. The area under the ROC curve shows that estimation of VAT by a BCM is a good predictor of the MetS and has a better capacity than WC and WHR to diagnose the MetS (Figs 2 and 3).

It is also remarkable that a VAT estimation $\geq$10 points has a sensitivity of 100% for diagnosing the MetS, allowing the early recognition of this condition that is associated with a higher cardiovascular risk, which can be reduced by adequate treatment (Sacks *et al.*, 1996; Chobanian *et al.*, 2003; Grundy, 2007).

In addition, BCM identifies excessive VAT, which is another predictor of cardiovascular diseases (Poirier & Eckel, 2002; Wang *et al.*, 2005; Bray *et al.*, 2008). Interestingly, BCM also identifies subjects with high VAT but normal WC (Fig. 2). These 'metabolically obese but normal-weight' subjects have reduced insulin sensitivity, increased abdominal adiposity, an atherogenic lipid profile and raised blood pressure (Thomas *et al.*, 2012).

Moreover, BCM estimation of body composition and REE has a good correlation with BIA and indirect calorimetry, thus allowing individualised therapy for each patient with respect to diet, exercise and follow-up (Ricciardi & Talbot, 2007). BIA occasionally provides information on regional fat distribution, although this requires more complex equipment and a longer time than BCM (Watson *et al.*, 2009). Furthermore, we have not found any studies evaluating the ability of BIA to diagnose the

**Table 1** Anthropometrical and biochemical characterisation categorised by the metabolic syndrome

| | MetS (+) ($n$ = 18) | MetS (–) ($n$ = 20) | $P$ |
|---|---|---|---|
| Waist circumference (cm) | 116.6 (17.6) | 99.8 (8.5) | <0.001 |
| Weight (kg) | 103 (20.4) | 86 (13.5) | <0.001 |
| BMI (kg $m^{-2}$) | 37.3 (4.4) | 32.8 (5.6) | <0.001 |
| Total cholesterol (mM) | 5.4 (0.9) | 5.3 (0.8) | 0.73 |
| HDL cholesterol (mM) | 1.3 (0.3) | 1.3 (0.3) | 0.36 |
| LDL cholesterol (mM) | 3.2 (0.7) | 3.6 (0.8) | 0.65 |
| Triglycerides (mM) | 1.7 (0.7) | 1.4 (0.38) | 0.09 |
| Serum glucose (mM) | 5.1 (0.5) | 4.5 (0.3) | 0.01 |
| VAT (points) | 14 (range 9–27) | 7 (range 2–12) | <0.001 |

Data are the mean (SD).
BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MetS, metabolic syndrome; VAT, visceral adipose tissue.

MetS. CT is considered one of the gold standards of VAT (Yoshizumi *et al.*, 1999; Shen *et al.*, 2004). In a small group of subjects, we have observed a good correlation between VAT estimation by BCM and CT (Baudrand, R., Domínguez, J.M., Tabilo, C., Figueroa, D., Jimenez, M., Eugenin, C., Carvajal, C., Moreno, M., unpublished data). Consistently, Ryo *et al.* (2005) reported an excellent correlation between abdominal CT and the use of a similar BCM.

This low cost BCM is easy to use, gives immediate results and requires minimal cooperation from the patient, who does not need sedation and is not exposed to radiation (Lee & Gallagher, 2008). Therefore, the capacity to estimate VAT, predict the MetS and measure REE and body composition could facilitate both the evaluation and follow-up of patients and hopefully also inspire action aiming to achieve a healthy lifestyle.

The present study has limitations. Not all of the recruited patients had complete biochemical parameters, although we did not exclude them to avoid bias and also increased our sample for BCM validation. The adequate selection of subjects and the strong correlation between VAT estimation and the anthropometric parameters of central obesity diminish the probability of bias. Also, our predictive capacity regarding the status of the MetS, although internally valid, may lack generalisability to populations other than Hispanics.

In conclusion, VAT estimation by a validated monitor has a highly positive correlation with anthropometric parameters of central obesity, and efficiently predicts the MetS. This simple and inexpensive method may become a useful instrument for identifying subjects with obesity-related metabolic disorders and provide follow-up in primary care practice.

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## Conflicts of interest, sources of funding and authorship

The authors declare that there are no conflicts of interest.
No funding is declared.
All authors critically reviewed the manuscript and approved the final version submitted for publication.

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