BEYOND BODY MASS INDEX: VISCERAL ADIPOSITY ASSESSMENT

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INTRODUCTION

Visceral adipose tissue (VAT) excess is a major risk factor for developing metabolic, cardiovascular and oncological diseases, independently from general obesity as assessed by body mass index (BMI). **Computed tomography scan** (CT-scan) and **magnetic resonance imaging** (MRI) provide a reproducible and accurate measurement of VAT. Both techniques can measure the volume of VAT in the whole peritoneal cavity, but a single slice measurement by either CT-scan or MRI is generally used as a criterion measurement of VAT. These techniques are often prohibitive due to cost, accessibility, and/or relatively high radiation delivery. **Simple anthropometric measurements** such as waist-to-hip ratio (WHR), waist circumference (WC) or abdominal sagittal diameter (SD) are widely used to assess abdominal fat deposition in the clinical setting or in studies involving large samples of participants. However, these measurements cannot differentiate between VAT and subcutaneous abdominal adipose tissue (SAAT) and are less accurate than biomedical imaging.

AIMS

To investigate whether the combination of a limited number of anthropometric measurements improves the VAT prediction, in a Mediterranean adult population of both genders with a large range of BMI and age.

We hypothesize that subtracting the most correlated anthropometric measurement with subcutaneous abdominal adipose tissue (SAAT) from the most correlated anthropometric measurement with visceral adipose tissue (VAT) and total abdominal adipose tissue (TAAT), as assessed by CT-Scan, provides the most accurate prediction of VAT by anthropometry.

SUBJECTS AND METHODS

Participants

- **71 women**:
  BMI: 31.37 ± 7.21 kg/m^2; min: 16.32 kg/m^2; max: 50.38 kg/m^2
  Age: 46.55 ± 15.42 years; min: 20 years; max: 77 years
- **43 men**:
  BMI: 30.14 ± 6.76 kg/m^2; min: 18.86 kg/m^2; max: 47.80 kg/m^2
  age: 46.95 ± 15.63 years; min: 18 years; max: 78 years

Anthropometry

In addition to weight, stature and BMI, **40 anthropometric measurements** were performed in all patients by a single investigator (HS), according to Lohmann, in order to provide estimates of:

- Abdominal adiposity: waist circumference (WC) at natural waist and at the umbilicus; waist-to-hip ratio (WHR); sagittal diameter (SD) with 2 different sets of calipers; transversal diameter (TD). All abdominal measurements were performed with the subjects both standing and supine;
- Subcutaneous adiposity: thigh circumferences at 3 levels, proximal (PTC), mid-thigh (MTC), and distal (DTC); other limb circumferences; thickness of multiple skinfolds.

Criterion measurement of visceral fat by CT-scan

A **single slice 10 mm CT-scan** at the L4-L5 level was acquired, using a **General Electric Medical System High Speed CTI® tomodensitometer** (40 Kv, 220 mA, acquisition time: 2 s). **VAT surface** was calculated with the software included in the apparatus. The attenuation interval chosen for adipose tissue was [-190; -30] Hounsfield units. VAT was delimitated manually.

Design of VAT prediction models and statistical analysis

All data are expressed as mean±sd. Statistics were performed using Statitica^{TM} for Windows^{TM}. VAT predictive models included:

- A single anthropometric parameter. Single-parameter models were tested using univariate linear regressions;
- A combination of 2 anthropometric parameters (to avoid time consuming assessment), plus 2 optional parameters among age, weight, stature and BMI;

The selection of multiple parameters was empirical, based on the hypothesis that optimal prediction of VAT require parameters that correlate highly with total abdominal adipose tissue (TAAT) and VAT, and others that correlate highly with subcutaneous abdominal adipose tissue (SAAT), since VAT=TAAT-SAAT. Models were tested using multiple linear regression, and selected in order to avoid redundancy. We also performed stepwise regressions to verify parameter selection. We assessed the accuracy of VAT prediction for selected models using Bland & Altman plots of the differences of estimates. For the relevance of the selected models for the diagnosis of VAT excess in a clinical setting, we determined the sensitivity (Se), specificity (Sp), positive and negative predictive value (PPV, NPV) of the models for predicting VAT>130 cm^2.

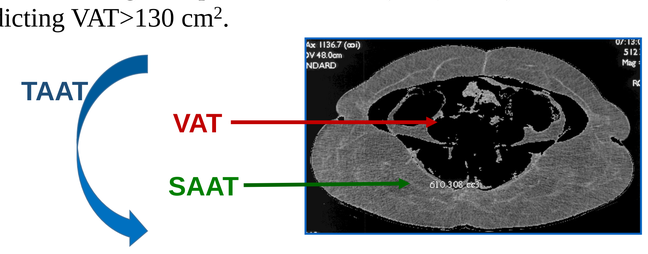

Figure 1: visceral fat by CT-scan, L4-L5 level

RESULTS

Single parameter prediction of visceral adipose tissue and subcutaneous abdominal adipose tissue

Women

	R (VAT)	R (TAAT)
SD	0.847	0.848
WC	0.835	0.952
WHR	0.814	0.705
TD	0.736	0.900
PTC	0.211	0.597
DTC	0.210	0.471
MTC	0.108	0.456

	R (SAAT)	R (TAAT)
Hip C	0.937	0.909
WC	0.897	0.952
TD	0.876	0.900
SD	0.828	0.848
PTC	0.718	0.597
MTC	0.575	0.456
DTC	0.543	0.471

Men

	R (VAT)	R (TAAT)
SD	0.833	0.774
WC	0.812	0.958
TD	0.810	0.918
WHR	0.778	0.700
DTC	0.453	0.684
PTC	0.238	0.610
MTC	0.216	0.530

	R (SAAT)	R (TAAT)
WC	0.882	0.958
Hip C	0.867	0.823
TD	0.825	0.918
SD	0.747	0.774
PTC	0.736	0.610
DTC	0.710	0.684
MTC	0.634	0.530

- Standing SD appears to be the best single anthropometric predictor of VAT in both genders, WC being nearly as powerful.
- PTC appears to be the most correlated anthropometric measurement with SAAT, while being the less correlated possible with VAT.

Prediction of visceral adipose tissue using models that combine multiple parameters

Women

	R	R^2	see $_{cm^2}$	Parameters included
Model 1	0.927	0.859	34.25	SD/PTC/Age/BMI
Model 2	0.914	0.836	36.88	WC/PTC/Age/BMI

Men

	R	R^2	see $_{cm^2}$	Parameters included
Model 1	0.890	0.792	49.78	SD/PTC/Age/BMI
Model 2	0.896	0.803	47.73	WC/PTC/Age

- 2 anthropometric measurements combined with age and BMI provide a good prediction of VAT.
  This model explains ~84% of VAT variance.
- Subtracting PTC, the most correlated anthropometric measurement with SAAT, from WC, the most correlated anthropometric measurement with VAT and TAAT, provides the most accurate prediction of VAT by anthropometry.
- WC explains almost the same variance as SD in the VAT predictive models, in addition to be easier to measure.

Accuracy of our selected anthropometric models to predict VAT

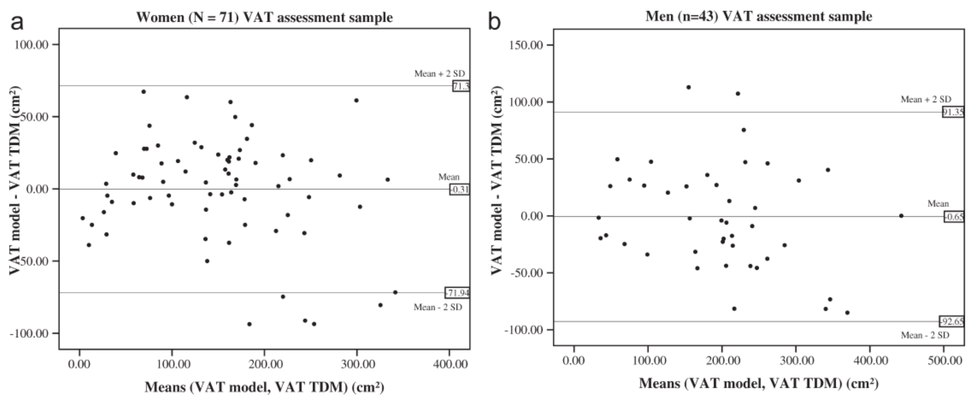

FIGURE 1 Bland and Altman plots of the differences between predicted (by our anthropometric model) and assessed (by TDM: Tomodensitometry) VAT values against means of VAT in the visceral adipose tissue assessment sample; amongst (a) 71 women and (b) 43 men.

Bland and Altman method showed the absence of systematic estimation error of VAT in our predictive models (no significant correlation showed).

Ability of selected models/equations to predict VAT excess (VAT > 130 cm^2)

Women

Parameters included	Se %	Sp %	VPP%	VPN%
WC/PTC/Age/BMI	**97.7**	**85.7**	**91.3**	**96.0**

Men

Parameters included	Se %	Sp %	VPP%	VPN%
WC/PTC/Age	**100**	**75**	**90.9**	**100**

- The models selected demonstrate high sensitivity and predictive values in both gender

CONCLUSIONS

1) **The combination of 2 simple anthropometric measurements together with age and BMI largely improves VAT prediction, compared to a single parameter.**

2) **Subtracting proximal thigh circumference, the most correlated anthropometric measurement with SAAT, from waist circumference, the most correlated anthropometric measurement with VAT and TAAT, provides the most accurate prediction of VAT by anthropometry.**

3) **Indirect anthropometric surrogates of limb fatness appear to improve substantially VAT prediction, probably because they provide an estimate of SAAT and help differentiate abdominal fat compartments.**

4) **Our selected VAT predictive models have been validated in the National Health and Nutrition Examination Survey III (10.000 individuals, 20 years follow-up), as being the most accurate anthropometric predictors of cardiometabolic biological abnormalities and cardiovascular, cancer-specific and all-cause premature mortality, when bioimaging methods are not available, compared to BMI and WC[1-3].**

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