

Research Article

Association between Abdominal Fat (DXA) and Its Subcomponents (CT Scan) before and after Weight Loss in Obese Postmenopausal Women: A MONET Study

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Introduction. Subcutaneous fat (ScF) and visceral fat (VF) measurements using CT scan are expensive and may imply significant radiation doses. Cross-sectional studies using CT scan showed that ScF and VF are significantly correlated with abdominal fat measured by DXA (AF-DXA). The association has not been studied after a weight loss. **Objective.** To determine (1) the associations between AF-DXA and ScF and VF before and after weight loss and (2) the associations between their changes. **Methods.** 137 overweight/obese postmenopausal women were divided in two groups (1-caloric restriction or 2-caloric restriction + resistance training). AF was assessed using DXA and CT scan. **Results.** Correlations between AF-DXA and ScF (before: $r = 0.87$, after; $r = 0.87$; $P < .01$) and, AF-DXA and VF (before: $r = 0.61$, after; $r = 0.69$; $P < .01$) are not different before and after the weight loss. Correlations between delta AF-DXA and delta ScF ($r = 0.72$; $P < .01$) or delta VF ($r = 0.51$; $P < .01$) were found. **Conclusion.** The use of AF-DXA as a surrogate for VF after weight loss is questionable, but may be interesting for ScF.

1. Introduction

Several health risks and metabolic disorders have been associated with obesity such as lipid abnormalities, insulin resistance, type 2 diabetes, cardiovascular diseases, orthopedics complications, and certain forms of cancer [1–3]. Indeed, several studies showed that an excessive accumulation of fat in the abdominal region (AF) is strongly related to health hazards [4], including several component of the metabolic syndrome (MetS) such as insulin resistance, dyslipidemia, and elevated blood pressure as well as with proinflammatory and prothrombotic states [1, 4–11].

In women, the menopause-induced loss of estrogens leads to an accumulation of AF rather than peripheral adiposity [12–14]. The AF is composed of two main different layers, subcutaneous fat (ScF) and visceral fat (VF) [15]. Currently, the excessive accumulation of VF is considered as the most deleterious fat depot for the metabolic profile and health [8, 12, 16–23], but excess of ScF is also linked to metabolism abnormalities mostly glucose metabolism disturbances [23–29] and elevated C-reactive protein levels in women [30]. Nonetheless, the implication of ScF in MetS remains unclear and has been reported to be less important than VF [1, 15, 23, 24, 27].

Studies showed that overweight and obese subjects engaged in diet- or exercise-induced weight loss programs can significantly reduce AF, ScF, and VF, which have also been correlated with improvements in the metabolic profile [31–34]. Interestingly, metabolic improvements have been reported even with weight losses as small as 5% to 10% [31–35]. Studies also reported that individuals participating in a structured exercise program can lose significant AF amount (particularly VF), even in the absence of body weight loss [32–34, 36]. Because of the metabolic and health risks associated with VF, it is important to promote weight loss strategies that specifically target decreases in VF.

The accurate measurement of AF, ScF and VF can be done using computed tomography (CT scan) or magnetic resonance imaging (MRI). In fact, the measurement of VF with these methods is expensive and limited due to the accessibility to the equipment. The use of CT scan has also raised some concerns regarding the exposition of subjects to radiation doses [37–39]. Hence, developing highly reliable surrogate measures of VF and ScF using simpler, less expensive and more widely available techniques would be highly useful [40]. Considering these criteria, AF measured by DXA (AF-DXA) may be an interesting alternative. A few cross-sectional studies reported that AF by DXA is significantly and strongly correlated with AF measured by CT scans (AF-CT) (r ranging from 0.86 to 0.98; $P \leq .001$) [38, 41, 42]. It remains to be determined, however, if changes in AF-DXA can correctly predict changes in ScF and VF after a weight loss intervention.

The main objectives of this study were (1) to determine the association between AF measured by DXA and ScF, VF and AF measured by CT scan after weight loss in obese postmenopausal women, (2) to examine associations between changes in these variables after weight loss. Finally a second-level objective is to evaluate if AF-DXA could be a good surrogate of single-slice CT scan assessment of ScF and VF after a weight loss and to detect changes induced by weight loss in these compartments.

2. Materials/Subjects and Methods

2.1. Subjects. The MONET project (Montreal Ottawa New Emerging Team in Obesity) is designed to investigate, using a randomized controlled design, the impact of resistance training during weight loss (6 months) on various parameters including body composition as previously reported [43, 44]. Briefly 137 overweight/obese postmenopausal women were randomly assigned in a 2:1 fashion to a 6-month caloric restriction diet (CR) alone or a CR diet + resistance training program (RT). During the 6-month weight loss phase, 30 women out of 137 dropped out of the study, yielding a dropout rate of 21.9%. Thus, 107 women (71 CR and 36 RT + CR) completed the 6-month weight loss phase [45]. Baseline characteristics of dropouts were not different from those of subjects who completed the study, except for lean body mass which was lower in dropouts (40.6 ± 3.8 versus 42.8 ± 6.6 , $P < .05$) (results not showed). This study was approved by the Université de

Montréal Ethics Committee. After receiving a complete verbal and written description of the experimental protocol and potential risks, each participant provided signed consent.

Women were eligible to participate if they were sedentary, overweight, or obese and did not present significant health complications. Complete inclusion and exclusion criteria have previously been reported [43]. For the purpose of this study, we first selected a sample composed of 131 obese post-menopausal women (57.6 ± 4.8 yrs) for whom we had all baseline anthropometric, DXA, and CT scan data. We use this sample to perform correlations at baseline between AF by DXA and ScF and VF by CT scan. Secondly, to assess differences between groups at baseline and to examine changes following the intervention within each group, we selected from the previous mentioned sample all women who completed the weight loss program and in whom we had all 6-month anthropometric, DXA, and CT scan data (total $n = 92$). These women were distributed as follows: CR group ($n = 64$) and CR + RT ($n = 28$).

2.2. Caloric Restriction Intervention with or without Resistance Training Intervention. All study participants entered a 6-month weight loss program aimed at reducing body weight by 10% using a standardized diet with 55%, 30%, and 15% of energy intake from carbohydrates, total fat, and protein according to the American Heart Association [46].

A subset also participated to a 6-month resistance training program. Details about these interventions have been previously reported [43].

2.3. Anthropometry. Body weight was measured to the nearest 0.1 kg on a calibrated scale (Balance Industrielle Montréal, Montréal, Québec, Canada) and subject's height was obtained with a standard stadiometer (Perspective Enterprises, Portage, MI, USA). Percentage of fat (%F) and total fat were measured using dual energy X-ray absorptiometry (DXA) (General Electric Lunar Prodigy, Madison, WI, USA; software version 6.10.019), as previously described [31, 47]. The amount of abdominal fat (AF-DXA) is automatically generated in the DXA body composition report obtained by a whole-body assessment, as well as other regions (arms and legs). During the procedure, subjects were asked to wear only a standard hospital gown while in the supine position. Calibration was performed daily with a standard phantom. In our laboratory, the intraclass coefficient correlation for test-retest for AT and lean body mass was 0.99 ($n = 18$).

2.4. Computed Tomography. A CT scanner (GE LightSpeed 16, General Electric Medical Systems, Milwaukee, WI, USA) was used to measure the visceral fat (VF) and the abdominal subcutaneous tissue (ScF) area. The sum of ScF and VF was used to calculate the abdominal fat by CT (AF-CT). Subjects were examined in the supine position with both arms stretched above their head. The position of the scan was established at the L4-L5 vertebral disc using a scout image of the body [31, 47]. We quantified VF by delineating

TABLE 1: Descriptive characteristics.

| | Baseline $n = 131$ | 6 months $n = 92$ | Changes $n = 92$ |
|--------------------------|--------------------|--------------------|------------------|
| Age (years) | 57.6 \pm 4.8 | | |
| Weight (kg) | 83.2 \pm 12.6 | 78.8 \pm 12.8* | -5.2 \pm 5.0 |
| BMI (kg/m ²) | 32.4 \pm 4.3 | 30.4 \pm 4.2* | -2.0 \pm 1.9 |
| WC (cm) | 95.8 \pm 9.2 | 91.0 \pm 9.3* | -5.0 \pm 4.0 |
| AF-DXA | 18.2 \pm 5.0 | 15.6 \pm 4.7* | -2.6 \pm 2.5 |
| AF-CT | 650.8 \pm 143.9 | 578.0 \pm 148.6* | -71.3 \pm 65.6 |
| ScF | 466.0 \pm 112.9 | 417.1 \pm 114.8* | -49.7 \pm 45.1 |
| VF | 184.8 \pm 55.2 | 160.9 \pm 57.1* | -21.6 \pm 29.9 |

Mean \pm SD.

*Significant difference within group between 0-month and 6-month measures, $P \leq .05$.

BMI: Body Mass Index (kg/m²); WC: Waist Circumference (cm); AF-DXA: Abdominal Fat by DXA (kg); AF-CT: Abdominal Fat by CT scan (cm²); ScF: Abdominal Subcutaneous Fat by CT scan (cm²); VF: Visceral Fat by CT scan (cm²).

the intraabdominal cavity at the internal most aspect of the abdominal and oblique muscle walls surrounding the cavity and the posterior aspect of the vertebral body. The abdominal ScF area was quantified by highlighting fat located between the skin and the external most aspect of the abdominal muscle wall. The cross-sectional areas of fat were highlighted and computed using an attenuation range of -190 to -30 Hounsfield Units (HU).

2.5. Statistical Analyses. Results are presented as the mean \pm standard deviation (\pm SD). First, unpaired t -tests were performed to compare groups, while ANOVA for repeated measures were used to examine changes following the intervention within each group and between groups (time \times group interaction). Since no difference was observed between groups for AF, ScF, and VF before and after interventions (results not shown), data were pooled for statistical analyses purposes. Finally, Pearson correlations were used to assess the association between AF-DXA (by DXA) and ScF, VF, and AF-CT (by CT scan). To perform Pearson correlation coefficients we considered all the women for whom we had complete data for AF-DXA, ScF, VF and AF-CT. These statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 15.0 (SPSS Inc., Chicago, IL, USA). Finally, we computed Z scores from our correlation coefficients to compare the slopes from pre- and postintervention correlations. The level of significance was set at $P \leq .05$.

3. Results

Descriptive characteristics are presented in Table 1. As previously reported, significant differences were found between baseline and postinterventions values [43]. Correlations between AF-DXA, AF-CT, ScF, VF and WC before and after weight loss were all statistically significant (Tables 2 and 3; all P -values $< .01$) and equivalent before and after the intervention. Pearson's correlations were also performed to assess association between changes in AF-DXA, AF-CT, ScF, VF, and WC (Table 4). Significant correlations were also

TABLE 2: Pearson's correlations between AF-DXA, AF-CT, ScF, VF, and WC before weight loss interventions.

| | AF-DXA | AF-CT | ScF | VF | WC |
|--------|--------|-------|-------|-------|----|
| AF-DXA | 1 | | | | |
| AF-CT | 0.92* | 1 | | | |
| ScF | 0.87* | 0.94* | 1 | | |
| VF | 0.61* | 0.69* | 0.39* | 1 | |
| WC | 0.86* | 0.84* | 0.73* | 0.70* | 1 |

* $P \leq .01$ by Pearson's correlation coefficient.

AF-DXA: Abdominal Fat by DXA (kg); AF-CT: Abdominal Fat by CT (SAT+VAT) (cm²); ScF: Abdominal Subcutaneous Fat by CT scan (cm²); VF: Visceral Fat by CT scan (cm²); WC: Waist Circumference (cm).

TABLE 3: Pearson's correlations between AF-DXA, AF-CT, ScF, VF, and WC after weight loss interventions.

| | AF-DXA | AF-CT | ScF | VF | WC |
|--------|--------|-------|-------|-------|----|
| AF-DXA | 1 | | | | |
| AF-CT | 0.92* | 1 | | | |
| ScF | 0.86* | 0.94* | 1 | | |
| VF | 0.67* | 0.72* | 0.43* | 1 | |
| WC | 0.89* | 0.87* | 0.79* | 0.69* | 1 |

* $P \leq .01$ by Pearson's correlation coefficient.

AF-DXA: Abdominal Fat by DXA (kg); AF-CT: Abdominal Fat by CT (SAT+VAT) (cm²); ScF: Abdominal Subcutaneous Fat by CT scan (cm²); VF: Visceral Fat by CT scan (cm²); WC: Waist Circumference (cm).

obtained between (1) delta AF-DXA and delta ScF ($r = 0.720$; $P < .01$), (2) delta AF-DXA and delta VF ($r = 0.506$; $P < .01$), and (3) delta AF-DXA and delta AF-CT ($r = 0.722$; $P < .01$).

4. Discussion

The direct measurements of ScF and VF using multiple slices by CT scan or using MRI are currently considered as gold standard methods [29, 48]. However, these techniques are expensive and not easily accessible. Furthermore, because

TABLE 4: Pearson's correlations between changes in AF-DXA, AF-CT, ScF, VF, and WC.

| | Delta AF-DXA | Delta AF-CT | Delta ScF | Delta VF | Delta WC |
|--------------|--------------|-------------|-----------|----------|----------|
| Delta AF-DXA | 1 | | | | |
| Delta AF-CT | 0.74* | 1 | | | |
| Delta ScF | 0.74* | 0.92* | 1 | | |
| Delta VF | 0.51* | 0.81* | 0.51* | 1 | |
| Delta WC | 0.58* | 0.57* | 0.52* | 0.47* | 1 |

* $P \leq .01$ by Pearson's correlation coefficient.

AF-DXA: Abdominal Fat by DXA (kg); AF-CT: Abdominal Fat by CT (SAT+VAT) (cm^2); ScF: Abdominal Subcutaneous Fat by CT scan (cm^2); VF: Visceral Fat by CT scan (cm^2); delta AF-DXA: ($\text{AF-DXA}_{6\text{month}} - \text{AF-DXA}_{\text{baseline}}$); delta AF-CT: ($\text{AAT-CT}_{6\text{month}} - \text{AAT-CT}_{\text{baseline}}$); delta ScF: ($\text{SAT}_{6\text{month}} - \text{SAT}_{\text{baseline}}$); delta VF: ($\text{VAT}_{6\text{month}} - \text{VAT}_{\text{baseline}}$); delta WC: ($\text{WC}_{6\text{month}} - \text{WC}_{\text{baseline}}$).

CT scans expose subjects to radiation doses (ranging from 1.5 mSv to 10 mSv; with an average of 6 mSv for a spine assessment), they might not be recommended for repeated measurements [38, 39]. For the purpose of the present study, only a single slice at L4-L5 was acquired, which corresponded to a dose of 0.012 mSv. Considering the lower cost of use, the shorter time of data acquisition and the lower ionizing radiation doses of DXA (about 0.0013 mSv for a whole-body assessment) [37–39], it could be an interesting alternative to assess changes in VF and ScF after weight loss interventions.

The present study showed that correlations obtained between AF by DXA and AF-CT subcomponents before and after weight loss ranged from moderate to good [15] and were all significant and are similar before and after weight loss. Our results are in agreement with those of Snijder et al. (2002) obtained in a study conducted in black and white men and women aged between 70 and 79 years [49]. However, results from other studies do not agree with ours [50, 51]. The latter studies showed abdominal fat measures by DXA to be strongly correlated with VF measured by CT scan or MRI (r between 0.83 and 0.90). Discrepancies between our results and others are most likely due to differences in populations studied. Indeed, in the present study, our population was composed of obese postmenopausal women as opposed to studies done in leaner men and women [50] or men only [51]. Hence, our results suggest that it is more difficult to predict changes in VF and ScF using DXA in obese postmenopausal women. This explains the lowest correlation between changes in AF-DXA and changes in VF in the present study.

Parallel to our observations pre- and post intervention, Clasey et al. also reported that DXA-derived AF is not a better predictor of VF by CT scan than WC [50]. In our study, AF-DXA accounted for only 45% of the variance of VF after weight loss, and only 26% of the variance of changes in this compartment as compared to 79% post intervention and 34% of changes for WC. Then, in our opinion, these relationships are too low to justify the use of a simple measure of abdominal fat using DXA to assess changes in the amount of visceral fat after weight loss. Thus, it seems

clinically more relevant to pursue using WC to estimate the amount of VF after weight loss.

Interestingly, we also observed better correlations for ScF with AF-DXA than for VF with AF-DXA, both before and after weight loss. Indeed, the simple measure of AF-DXA accounted for 74% of the variance of ScF after weight loss, and for 76% of the variance of its changes. These results suggest that DXA may be an interesting surrogate to CT scan to estimate amount of ScF after weight loss and its changes, depending on the precision required.

Nonetheless, other authors have developed equations using anthropometric and/or DXA measures to estimate VF accumulations in order to downplay the limitations associated with the use of indirect measures of body fat distribution [16, 38, 41, 42, 49–55]. For example, Garaulet et al. (2006) developed a predictive equation of VF using 3 anthropometric variables (triceps skinfold, sagittal diameter and coronal diameter). The authors reported a significant but moderate correlation with VF measured by CT scan ($r = 0.68$; $P < .0001$) [52]. In another study conducted in 71 overweight and obese subjects (27 men and 44 women, aged between 16 and 70 years), Bertin et al. (2000) developed an equation strongly correlated with VF measured by CT scan ($r = 0.86$; $P < .0001$) [16]. Their equations must however be used with caution since, to our knowledge, they had never been validated in another population including weight-reduced obese individuals.

In conclusions, cross-sectional analyses revealed good to very good correlations between AF-DXA and ScF or AF-CT before and after weight loss. On the other hand, changes in AF-DXA were only moderately correlated to changes in VF. In the light of our results, the use of CT scan remains the best approach to precisely quantify the effect of weight loss on VF. However, DXA may be an interesting surrogate to estimate the amount and changes in total abdominal fat or ScF before and after a weight loss intervention in obese postmenopausal women.

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Conflict of Interests

The authors have no conflict of interests to disclose.

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