Usefulness of waist circumference as a marker of abdominal adiposity in peritoneal dialysis: a cross-sectional and prospective analysis

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Abstract

**Background.** Waist circumference (WC) has been well recognized as a surrogate marker of abdominal adiposity. In peritoneal dialysis (PD) patients, however, aspects related to this dialysis modality, such as abdominal distension, presence of catheter and frequent hernia, raise questions regarding the reliability of WC measurements. Herein, we investigated for the first time whether WC is a reliable marker of abdominal adiposity in PD population.

**Methods.** This study included 107 prevalent PD patients [56% male, age 52 ± 17 years, 35% diabetics, body mass index (BMI) 24.8 ± 3.9 kg/m²]. WC measured at umbilicus level was evaluated against the trunk fat assessed by dual-energy x-ray absorptiometry at baseline and after 6 months. All measurements were taken with the empty abdominal cavity.

**Results.** At baseline, a strong correlation of WC with trunk fat (r = 0.81; P < 0.001) was observed. Adjusting for...
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gender, age, dialysis vintage and BMI, WC was independ-ently associated with trunk fat ($\beta = 0.30; P < 0.001; R^2 = 0.77$). The agreement between WC and trunk fat was 0.59 (kappa statistic) and the area under the curve was 0.90. In the prospective evaluation, we observed that changes in WC correlated with changes in trunk fat as well ($r = 0.49; P < 0.001$). The kappa statistic of 0.48 remained indicative of a moderate agreement between the methods. The receiver operating characteristic curve analysis showed that WC was sensitive to detect changes in trunk fat (area under the curve 0.76). In the logistic regression analysis adjusting for gender, age and BMI, changes in WC were independently associated with changes in trunk fat.

Conclusion. The simple anthropometric method of WC is a reliable marker of abdominal adiposity in PD patients.

Keywords: abdominal adiposity; chronic kidney disease; peritoneal dialysis; trunk fat; waist circumference

Introduction

There is increasing evidence that abdominal obesity exerts an important role in the cardiometabolic abnormalities among chronic kidney disease (CKD) patients [1–4]. Computed tomography and magnetic resonance have been considered as the gold standard methods to evaluate abdominal adiposity. However, those methods are costly and often unavailable for clinical and research purposes. Thus, trunk fat measured by dual-energy x-ray absorptiometry (DEXA) has been suggested as a good alternative for estimating abdominal adiposity. In fact, a strong correlation between trunk fat and abdominal fat, measured by using gold standard methods, has been demonstrated by several studies [5–8]. Nevertheless, DEXA is also not easily available in the clinical practice. Therefore, simple and inexpensive methods to estimate central adiposity continue to be developed and tested.

Waist circumference (WC) is a practical method that has been mostly used as a surrogate for abdominal adiposity in the general population and in different clinical conditions [9–12]. A strong association between WC and abdominal fat assessed by computed tomography has been recently confirmed in CKD patients not on dialysis [13]. In peritoneal dialysis (PD) patients, particular aspects related to this dialysis modality (e.g. abdominal distension, presence of catheter and frequent hernia) raise questions regarding the reliability of WC as a marker of central adiposity in these patients; however, this issue has not been investigated so far. Therefore, in this study, we tested whether WC is a reliable marker of abdominal adiposity in PD patients.

Materials and methods

Patients

One hundred and seven patients undergoing PD (37 on continuous ambulatory peritoneal dialysis and 70 on automated peritoneal dialysis) were recruited from a single dialysis unit. Only patients >18 years, undergoing PD for >3 months, free of peritonitis for at least 3 months and with no catabolic condition were included in the study. Exclusion criteria were treatment with corticosteroid or immunosuppressive drugs, presence of ascite, severe hernia or malignant disease.

Written informed consent was obtained from each patient. The study was approved by the Ethics and Research Committee of the Federal University of São Paulo.

Methods

Study design and protocol. In this 6-month prospective study, all patients were initially submitted to a first interview in order to meet the inclusion criteria and to obtain informed consent. Patients were then instructed to collect the drained dialyzerate for a 24-h period. Those patients with residual renal function were also instructed to collect 24-h urine. Within 1–3 weeks later, patients were admitted to the clinic in 12-h fasting and underwent nutritional and laboratory assessments with emptied peritoneal cavity. During the 6 months of follow-up, 6 patients died, 3 were moved to hemodialysis, 2 had received kidney transplants, 3 withdrew consent and 16 patients did not undergo baseline or 6-month assessments of trunk fat and/or WC.

WC and nutritional evaluation. Measurements of WC were taken with the empty abdominal cavity in the same day of DEXA assessment. The WC was measured at the umbilicus level at the end of expiration using a flexible plastic tape measure while patients were standing with their weight equally distributed on both feet and head facing straight forward. The mean of three measures was considered for analyses. All WC measurements were performed by the same trained observer. In a previous study including nondialysis CKD patients [14], the intra-observer variability of the WC was shown to be very low (0.01 ± 0.46 cm for two repeated measurements; $P = 0.83$) with a narrow limit of agreement ($−0.89$ to 0.91 cm; 95% confidence intervals) according to the Bland and Altman analysis.

Body mass index (BMI) was calculated as body weight divided by height squared [15], and nutritional status was evaluated by using the 7-point scale Subjective Global Assessment [16].

Dual-energy x-ray absorptiometry. Trunk fat was assessed by DEXA method using a scanner DPX model (Lunar Radiation Corp., Madison, WI). This instrument uses an energy-sensitive cadmium-zinc-telluride array detector that allows for a total body scan to be performed in 4–5 min, with the patient in supine position, and delivers a very low-radiation dose of $−0.037$ mrem. A standard soft tissue examination includes total body and regional measurements of trunk, arms and legs to analyze body composition according to a three-compartment model including fat mass, lean tissue and bone mineral content.

Laboratory parameters. Blood samples were drawn after an overnight fast of 12 h. Serum and dialyze creatinine and urea were determined by a standard autoanalyzer. The serum albumin was measured by bromcresol green method and high-sensitive C-reactive protein (CRP) by means of immunochromiluminescence. Total weekly Kt/V of urea and creatinine clearance (CrCl) were calculated using standard methods.

Statistical analysis. Data are expressed as mean ± SD for normally distributed variables and as median and interquartiles for skewed variables. Dialysis vintage, CRP and total weekly CrCl did not present normal distribution and were transformed into natural logarithms for statistical tests. Paired or independent Student’s $t$-test was applied, as appropriate. Pearson correlation test was used to evaluate variables that were associated with WC and trunk fat. Multiple linear regression analysis was performed to evaluate the independent relationship between WC and trunk fat in the cross-sectional analysis and a logistic regression analysis was applied to investigate whether changes in WC were associated with changes in trunk fat during the 6-month follow-up. The multiple linear regression was also used to develop a specific trunk fat predictive equation by using WC and relevant parameters. Bland and Altman plot analysis was then applied in order to evaluate the agreement between the trunk fat predicted by equation and the trunk fat measured by DEXA. This approach provided the calculation of error and the limits of agreement ($±1.96$ SD from the mean error) between the methods. The agreement between WC and trunk fat was evaluated by the kappa statistic test. In this test, values from 0.41 to 0.60 are considered as moderate agreement and values from 0.61 to 0.80 as substantial agreement [17]. The predictability of trunk fat by WC values was assessed by the receiver operating characteristic (ROC) curve analysis, using the median of trunk fat by DEXA as a cutoff point. Differences with $P$-values <0.05 were considered
Results

Cross-sectional analysis

The demographic, clinical and nutritional characteristics of the patients are summarized in Table 1. Age varied from 18 to 84 years. Causes of CKD were hypertensive nephrosclerosis in 25 patients (23.5%), diabetic nephropathy in 25 patients (23.5%), chronic glomerulonephritis in 10 patients (9.3%), polycystic kidney disease in 5 patients (4.6%), undetermined cause in 28 patients (26.1%) and other causes in 14 patients (13.0%). Fifty percent of the patients had a BMI between 18.5 and 25 kg/m², 47% were overweight or obese and 3% were underweight. Twenty-five patients (25%) had serum albumin levels < 3.5 g/dL. According to the subjective global assessment, 64 patients (59.8%) were well nourished, 43 (40.2%) were mild to moderately malnourished and none was classified as severely malnourished.

As expected, body fat was higher and lean body mass was lower among women in comparison to men. No difference between women and men was observed regarding WC and trunk fat.

A strong correlation between WC and trunk fat was found (r = 0.85 and r = 0.86; P < 0.001, male and female, respectively; Figure 1). WC correlated positively with age (r = 0.34, P < 0.001) and negatively with dialysis vintage with a borderline significance (r = −0.19, P = 0.05). Trunk fat was directly associated with BMI (r = 0.79, P < 0.01) and inversely with dialysis vintage (r = −0.29, P = 0.002). There was no association of both WC and trunk fat with serum albumin or CRP.

As can be seen in Table 2, adjusting for gender, age, dialysis vintage and BMI, WC was independently associated with trunk fat. The kappa statistic analysis showed a moderate agreement (0.59) between WC and trunk fat. In addition, the ROC curve analysis revealed WC as a strong predictor of trunk fat (area under the curve 0.90; Figure 2).

The multiple linear regression allowed us to develop an equation by using WC and relevant parameters to predict trunk fat as follow:

\[
\text{Trunk fat (kg)} = (1.90 \times \text{gender}) - (0.03 \times \text{age}) - (0.78 \times \text{dialysis vintage}) + (0.20 \times \text{BMI}) + (0.30 \times WC) - 20.4,
\]

where gender = 1 if female or 0 if male; age in years, dialysis vintage in months, BMI in kilograms per square meter and WC in centimeter.

The Bland and Altman analysis between predicted and measured trunk fat is shown in Figure 3. A strong correlation was found between predicted and measured trunk fat (r = 0.88, P < 0.001).

Prospective analysis

Measurements of WC and trunk fat were repeated in 77 patients after 6 months. Trunk fat increased in 50% of the patients, reduced in 47% and maintained in 3%. Changes in WC correlated with changes in trunk fat (r = 0.44, r = 0.53, P < 0.01, male and female, respectively; Figure 4). The kappa statistic analysis resulted a coefficient of 0.48, indicating a moderate agreement between changes in WC and changes in trunk fat.

The ROC curve analysis exhibited an area under the curve of 0.76 (Figure 5). In the logistic regression analysis adjusting for gender, age and BMI, increase of WC was independently associated with gain in trunk fat (Table 3).

Discussion

In the present study, cross-sectional and prospective analyses demonstrated that WC is a reliable marker of abdominal adiposity in PD patients. This finding is of paramount importance in view of the increased prevalence of central obesity and its subsequent deleterious effects among CKD patients [1–4, 18, 19].

Body fat gain is a common finding in PD patients, particularly in the commencing of dialysis therapy [20–22]. Moreover, there is evidence that accumulation of body fat occurs predominantly in the abdominal area. Indeed, a study that included 19 incident PD patients showed that visceral fat, measured by computed tomography, increased during 15 months of follow-up [23]. More recently, an investigation including 60 patients demonstrated that both visceral fat as well as subcutaneous fat increased during the first 6 months on PD [24]. In the current study, there was a large variability in trunk fat changes. While 50% of the

| Table 1. Demographic, clinical and biochemical data of the patients at baseline (n = 107)* |
|---------------------------------|------|
| Age (years)                   | 52.3 ± 16.5 |
| BMI (kg/m²)                   | 24.8 ± 3.9  |
| Dialysis vintage (months)     | 13 (5.8–29.8) |
| Diabetes, %                   | 35 (32.7)   |
| Serum albumin (g/dL)          | 3.7 ± 0.4   |
| CRP (mg/dL)                   | 0.38 (0.13–1.20) |
| Dialysis parameters           |          |
| Total weekly CrCl (L/week per 1.73 m²) | 61.7 (45.1–83.6) |
| BMI (kg/m²)                   |          |
| Men                            | 24.5 ± 3.5  |
| Women                          | 25.2 ± 4.3  |
| Body fat (kg)                  |          |
| Men                            | 16.3 ± 7.1  |
| Women                          | 22.1 ± 8.8b |
| Lean body mass (kg)            |          |
| Men                            | 50.2 ± 7.3  |
| Women                          | 38.3 ± 4.6b |
| Trunk fat (kg)                 |          |
| Men                            | 9.8 ± 4.4   |
| Women                          | 11.5 ± 4.8  |
| WC (cm)                        |          |
| Men                            | 92.5 ± 10.4 |
| Women                          | 89.9 ± 11.8 |

*Values are mean ± SD or median and interquartiles.

**P < 0.01, men versus women.
patients increased trunk fat, 47% reduced and 3% maintained.

Although trunk fat by DEXA does not differentiate between visceral and subcutaneous abdominal fat, it has been considered as a reliable marker of central adiposity. Accordingly, there are several studies showing substantial agreement between trunk fat by DEXA and total abdominal fat by computed tomography or magnetic resonance [5–8]. In CKD patients not on dialysis, we have recently demonstrated that the trunk fat was strongly correlated with both visceral and subcutaneous fat assessed by computed tomography [13]. Additionally, a direct association between trunk fat mass and inflammatory markers has been demonstrated by Axelsson et al. [25] in a study including nondialyzed CKD patients. In the present study, we did not find association between trunk fat or WC and inflammatory markers. It is possible that the complex physiopathological mechanisms involved with inflammatory state in PD population might have obscured such association.

The relationship between obesity and clinical outcomes has not been clearly established in PD population. However, visceral fat accumulation has been suggested as one of the possible factors involved with increased risk of cardiovascular morbidity and mortality in these patients [23]. In fact, a study demonstrated that visceral fat estimated by bioelectrical impedance analysis was associated with increase in pulse-wave velocity and reduction in brachial artery flow-mediated dilation in patients undergoing PD therapy [4]. Therefore, monitoring abdominal adiposity can be of value in the routine care of PD population.

Among the simple methods available for estimating abdominal adiposity, WC has been the most accepted and widely used in the clinical practice as well as in the epidemiological research. A strong relationship between WC and abdominal adiposity assessed by the gold standard methods has been demonstrated by several studies in the general population [9–12]. In CKD not on dialysis, Sanches et al. [13] showed in a cross-sectional study that WC was strongly correlated with total abdominal fat (visceral and subcutaneous) measured by computed tomography. Moreover, the authors found that WC was associated with cardiovascular risk factors similarly to visceral fat. In a subsequent study including the same cohort, Velludo et al. [14] found a fair agreement between WC and visceral fat when the measurements were analyzed prospectively.

In accordance with our results, other studies in non-CKD subjects have found a strong correlation between WC and trunk fat evaluated by DEXA [12, 26–29]. A direct association of WC with all-cause and cardiovascular death has been recently documented in a large cohort of hemodialysis patients [30]. Yet, it has been reported that abdominal obesity assessed by WC modifies the relationship of the adipokines leptin and adiponectin and of triglyceride with mortality in hemodialysis patients [31, 32]. Thus, WC has been increasingly established as an important tool to be part of the care of CKD patients.

In PD patients, albeit an association of WC with some metabolic parameters such as leptin and adiponectin has been demonstrated, the ability of WC in predicting abdominal adiposity has not been investigated [33, 34]. Some aspects related to the PD therapy such as abdominal distension due to the fluid infusion into the peritoneal cavity [35], presence of catheter and hernia might compromise the accuracy of WC measurements in this population. Indeed, the use of WC in PD patients has been avoided by some...

Table 2. Linear and multiple linear regression analysis using trunk fat as the dependent variable (n = 107)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>95% Confidence interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univariate (R² = 0.66)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.34</td>
<td>0.30 to 0.39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multivariate (R² = 0.77)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender (female)</td>
<td>1.90</td>
<td>0.91 to 2.90</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>−0.03</td>
<td>−0.06 to 0.001</td>
<td>0.05</td>
</tr>
<tr>
<td>Dialysis vintage (months)</td>
<td>−0.78</td>
<td>−1.23 to −0.34</td>
<td>0.001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>0.20</td>
<td>−0.06 to 0.45</td>
<td>0.14</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.30</td>
<td>0.20 to 0.39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Constant</td>
<td>−20.4</td>
<td>−26.25 to −15.65</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Fig. 1. Correlation between trunk fat and WC in 60 men (filled diamonds) and 47 women (unfilled diamonds) on PD therapy at baseline.

Fig. 2. ROC curve analysis of WC and trunk fat of 107 PD patients at baseline.
investigators [36, 37]. However, taking into consideration some features such as emptied abdominal cavity, absence of severe hernia and, finally, standardization and training of the WC technique, we suggest WC can be reliably used for monitoring abdominal adiposity in this particular group of patients.

The application of DEXA method as a reference might constitute a limitation in the present study. Nonetheless, there are sufficient data in the literature showing the strength of trunk fat by DEXA in predicting total abdominal adiposity assessed by gold standard methods [5–8]. We also recognize that the results herein are based on a relatively small cohort of PD patients. Thus, the agreement of WC with abdominal fat, especially with visceral fat, is of great interest for future investigations among patients on PD therapy.

In conclusion, the cross-sectional and prospective evaluation demonstrated that the simple anthropometric method of WC is a reliable marker of abdominal adiposity in PD patients. Further studies are warranted in order to validate the WC-derived equation of trunk fat besides examining the predictive power of WC measurement for morbidity and mortality in PD population.

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Conflict of interest statement. None declared.

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