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## How useful is waist circumference for assessment of abdominal obesity in Korean pre-menopausal women during weight loss?

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### Abstract

Asian women are known to have a larger amount of abdominal fat (AF) for the same level of BMI compared with Caucasian and African-American women. This study was aimed to determine whether waist circumference (WC) could be useful as an index of AF compared with AF measured by dual energy x-ray absorptiometry (DXA) before and after a weight-loss program in Asian women. Thirty-eight healthy, pre-menopausal obese Korean women (body fat percent > 30%) were enrolled and followed during a 6-week weight-loss program including herbal formula, calorie restriction, and exercise. Anthropometry and DXA measurements were performed before and after weight-loss. A specific region of interest (ROI, L2-iliac crest) by DXA was correlated with anthropometry at baseline: WC ( $\gamma = 0.91$ ) > BMI ( $\gamma = 0.87$ ) > Waist-Height ratio (WHtR,  $\gamma = 0.82$ ) > WHR ( $\gamma = 0.46$ ); and after weight loss: BMI ( $\gamma = 0.88$ ) > WC ( $\gamma = 0.84$ ) > WHtR ( $\gamma = 0.82$ ), all  $p < 0.01$ . The change in DXA ROI showed a reasonable correlation with change in anthropometry: BMI ( $\gamma = 0.63$ ,  $p < 0.01$ ) > WC ( $\gamma = 0.39$ ,  $p < 0.05$ ) > WHtR ( $\gamma = 0.37$ ,  $p < 0.05$ ). A stepwise multiple regression analysis revealed that 83% of the variance in DXA derived AF was explained by WC at baseline, WC and BMI at follow-up, respectively. This study suggests that WC could be a good predictor of AF for Korean pre-menopausal women.

### Keywords

abdominal fat; Dual energy x-ray absorptiometry; obesity; waist circumference; fat distribution

## INTRODUCTION

It is well-known that abdominal subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT) are related with several chronic diseases such as diabetes<sup>1,2</sup> and cardiovascular disease.

<sup>3</sup> Asian women have a tendency to have a higher amount of abdominal fat for the same BMI

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### AUTHOR DISCLOSURES

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compared to Caucasian and African-American women.<sup>4</sup> A normal BMI however, does not necessarily infer normal levels of abdominal fat. Therefore, when assessing adipose tissue distribution for detecting risk of obesity related diseases, it is important to acquire an appropriate index of central obesity.

The most sensitive methods available to quantify intra-abdominal fat include imaging techniques, specifically computerized tomography (CT) and magnetic resonance imaging (MRI). MRI has become the more popular technique and is used for the in-vivo assessment of organs and tissues at the whole-body level with no risk of radiation. But limitations associated with both CT and MRI include high cost and a risk of ionizing radiation with CT.<sup>5</sup>

Dual energy x-ray absorptiometry (DXA) has been used to measure body composition as an advanced laboratory based method for close to two decades. DXA allows for the assessment of regional and total body fat, lean tissues, and bone mineral content.<sup>6,7</sup> The advantages of DXA over CT and MRI as a means of estimating fat distribution include: relative ease of access to systems, simplicity of measurements, relatively low cost, and lower radiation exposure. Relative to waist circumference, DXA predicts fat mass with greater accuracy and reproducibility, making it easier to compare data from different studies. However, a major disadvantage of DXA is that it does not separate intra-abdominal and subcutaneous fat tissues.<sup>8-12</sup>

To acquire information specific to abdominal fat mass by DXA, over and above that provided by the conventional DXA trunk region, a specific Region of Interest (ROI) has been applied to estimate fat mass in the abdomen, excluding bony structure of ribs and spine. The conventional DXA trunk fat region (CV, coefficient of variation = 0.728%) includes chest, abdomen, and pelvis.

In 2002, Park *et al.* reported that DXA ROI of the upper L2-lower L4 ( $\gamma = 0.85, 0.96$ , respectively) and of upper L2-upper iliac crest ( $\gamma = 0.84, 0.97$ , respectively) shows high correlation with total VAT and abdominal adipose tissue (abdominal VAT plus SAT) by MRI.<sup>13</sup>

Several anthropometric indexes, such as waist circumference, waist to thigh circumference, waist to hip ratio (WHR), and sagittal abdominal diameter have been applied as surrogate measures of abdominal fat mass. Waist circumference (WC) is the most frequently used index of abdominal obesity in clinics due to its high relation with visceral fat in comparison with other anthropometric indexes<sup>14,15</sup> and simplicity of measurement and analysis.<sup>16</sup>

The aim of this study was to determine whether WC is a valid technique for measuring abdominal obesity before and after weight-loss programs compared to a DXA ROI in obese pre-menopausal Korean women.

## MATERIALS AND METHODS

### Subjects

Overweight (body fat percent > 30% or BMI > 25kg/m<sup>2</sup>) pre-menopausal Korean women ages 24 and 45 years were enrolled after providing written consent, from 1st April to 31st July, 2003. Subjects underwent a DXA (Prodigy, GE Lunar, USA) scan before and after a 6-week weight-loss program. This study was approved by the Institutional Review Board of Kyung Hee Oriental Medical Center. Fifty women were recruited and 12 dropped out during the study leaving 38 completers. Inclusion criteria required the subjects to be non-exercising, non-smoking, and not taking medications that could potentially influence body composition. Participants with diabetes mellitus, renal or hepatic problem, change of body weight over 3kg

during previous 3 months, possibility of pregnancy, and taking oral contraceptives were excluded from this study. Data from a participant with a compliance rate of less than 70% was removed from analysis. Recruitment was done through newspaper advertisements and internet websites.

## Protocol

Volunteers were provided with a traditional Korean herbal formula (Slim-diet) which is made as powder in Kyung Hee university oriental medical center pharmacy. Formula was taken 3 times a day, 30 minutes after each meal for 6 weeks. The ingredients of the formula are listed in Table 1. All of the contents are approved by the Korean FDA as food. Volunteers were informed that the formula was to help control their weight. In addition, a calorie-reducing diet was prescribed for each participant for the purpose of reducing estimated daily energy intake by 1000kcal/day thereby providing subjects with a daily energy intake of > 1200kcal/day. Participants had to personally decide what to eat and were required to maintain this prescribed diet for 6 weeks. Participants were required to walk or jog outdoors 3 times a week, for over 30 minutes. Participants were required to write a self-reporting diary so that the study staff could monitor their daily calorie intake and exercise.

## Anthropometrics

Body weight and height were measured to the nearest 0.1kg and 0.5cm respectively, wearing a hospital gown. Waist circumference and hip circumference were measured by the same observer twice according to the World Health Organization (WHO) method, mid-point between the lower end of the rib cage and top of the iliac crest in a standing position, which is usually 3cm above the anterior superior iliac spine.<sup>17</sup>

## Dual-Energy X-ray Absorptiometry (DXA)

Fat free mass (FFM, body weight minus total body fat), bone mineral content (BMC) were measured with a whole-body DXA scanner (Prodigy, GE Lunar, USA) using version 9.3 software. A specific abdominal region of interest (ROI, upper L2 – upper iliac crest) was analyzed for fat tissue.<sup>13</sup> Eight liters of methanol and water in bottles, simulating fat and fat-free soft tissues, were scanned daily as soft-tissue quality control markers. The range of measured CV for methanol and water over the study period was 0.062% and 0.112%. A DXA planogram demonstrating DXA ROI is presented in Figure 1.

## Statistical Analysis

All values are presented as mean  $\pm$  SD. The statistical significance of the correlation between DXA ROI and WC was verified through correlation analysis (Pearson's correlation) and evaluated by simple linear regression analysis (SPSS 11.0 for windows). A *p*-value less than 0.05 was considered statistically significant.

# RESULTS

## Demographic characteristics of subjects

Subjects were 38 pre-menopausal Korean women between the ages of 24 and 45 and with a BMI of 26.2 to 41.0kg/m<sup>2</sup>. After the weight-loss program, BMI decreased to between 26.0 and 39.6kg/m<sup>2</sup>, showing statistically significant loss in weight. Eighteen subjects at baseline and 13 at follow-up had a BMI greater than 30kg/m<sup>2</sup>. Seven subjects at baseline and 5 at follow-up had a BMI greater than BMI 35kg/m<sup>2</sup>. All subjects' BMI were less than 41kg/m<sup>2</sup>. Subject demographic and anthropometric characteristics are summarized in Table 2. DXA values at baseline and follow-up were also significantly reduced except for BMC (Table 3). The safety and efficacy of 'Slim-Diet' was reported previously by Song *et al.*<sup>18</sup>

### Association between DXA and anthropometry before and after weight-loss

Waist circumference showed the strongest correlation with DXA ROI and DXA trunk at baseline and BMI showed the highest correlation at follow-up. Correlations between DXA ROI and WC at baseline and follow-up ( $\gamma = 0.91, 0.84$ , respectively,  $p < 0.01$ ) were not significantly different from the correlations between BMI ( $\gamma = 0.87, 0.88$ , respectively,  $p < 0.01$ ) and WHtR ( $\gamma = 0.82, 0.82$ , respectively,  $p < 0.01$ ). Correlations between DXA ROI and WHR were the lowest at baseline ( $\gamma = 0.46, p < 0.01$ ) and were not significantly correlated at follow-up ( $\gamma = 0.23, p > 0.05$ ) (Table 4).

### Association between change of DXA ROI and anthropometry during weight-loss

The change in DXA ROI ( $\Delta$ ROI) showed significant correlations with  $\Delta$ WC and  $\Delta$ WHtR ( $\gamma = 0.39, 0.37$ , respectively, all  $p < 0.05$ ) whereas the change in DXA conventional trunk fat ( $\Delta$ trunk fat) was not significantly correlated with  $\Delta$ WC or  $\Delta$ WHtR ( $\gamma = 0.20, 0.19$ , respectively, all  $p > 0.05$ ). The change in DXA ROI ( $\Delta$ ROI) was also highly correlated with weight and BMI ( $\gamma = 0.64, 0.63$ , respectively, all  $p < 0.01$ ) (Table 5).

### Prediction of DXA ROI through anthropometry

Linear regression analysis ( $y =$  abdominal fat, DXA ROI,  $x =$  WC) with DXA ROI as the dependent variable revealed that 83% and 71% of the variance in abdominal fat was predicted by WC at baseline and follow up. Fifteen percent of the variance for change of abdominal fat was predicted by WC (data not shown).

The result of a stepwise multiple regression analysis showed that 83% of the variance in AF (DXA ROI) was predicted by WC at baseline. After weight-loss, 83% of the variance in AF was predicted by BMI (77%), when WC (6%) was included as independent variables. The change of AF was predicted by BMI (40.3%) (Table 6).

## DISCUSSION

WC is a well-known predictor of abdominal VAT and SAT.<sup>19</sup> In 2001, the National Cholesterol Education Program – Adult Treatment Panel III (NCEP-ATP III) included WC as a risk factor for the metabolic syndrome.<sup>20</sup> WC could possibly be a better predictor of risk of obesity for Asians as Asians have a tendency to have a higher percentage body fat and visceral fat than Caucasians and African Americans within the same BMI.<sup>21,22</sup> However, the correlations between WC and VAT can range from 0.4 to 0.9, depending on sex, age, and severity of obesity. In older women, WC was shown to have a stronger correlation with total body fat ( $\gamma^2 = 0.69$ ) than VAT ( $\gamma^2 = 0.40$ ).<sup>23</sup> But in pre-menopausal obese women, it has been reported that WC is strongly correlated with VAT by MRI ( $\gamma = 0.75$ ).<sup>24</sup> In the current study, participants were limited to pre-menopausal female.

Dual energy x-ray absorptiometry is a good method for body composition measurements as it differentiates three basic body components: bone mineral content, body fat, and lean tissue. However DXA does not distinguish intra-abdominal fat from subcutaneous fat. Because AF contains anterior and posterior subcutaneous fat, AF by DXA is a better predictor of total AF than intra-abdominal fat alone. In obese women, it has been reported that DXA was well correlated with VAT by MRI ( $\gamma = 0.74$ ).<sup>24</sup> Other studies carried out on obese women reported a similar correlation ( $\gamma$  range = 0.72 to 0.99) between AF measured by DXA and VAT measured by CT.<sup>9,11,12</sup>

To our knowledge, no study has previously compared differences before and after a weight-loss program. The present study indicates that a DXA ROI and DXA trunk fat have high correlations with WC, BMI, and WHtR before and after weight-loss in obese pre-menopausal

Korean women. Highly correlated with DXA ROI were WC > BMI > WHtR at baseline ( $\gamma = 0.91, 0.87, 0.82$ , respectively and  $p < 0.01$ ) and BMI > WC > WHtR at follow-up ( $\gamma = 0.88, 0.84, 0.82$ , respectively and  $p < 0.01$ ).

The change in a DXA ROI ( $\Delta$ ROI) revealed the highest correlation with BMI ( $\gamma = 0.63, p < 0.01$ ), followed by WC and WHtR ( $\gamma = 0.39, 0.37$ , respectively,  $p < 0.05$ ). The change in conventional DXA trunk fat ( $\Delta$ trunk fat) failed to show a significant correlation with  $\Delta$ WC even after adjustment for age and total body fat, but was correlated with  $\Delta$ BMI ( $\gamma = 0.44, p < 0.01$ ).

We hypothesized that WC would be a good measure for the assessment of AF in Asian obese women in both cross-sectional and longitudinal studies where the latter reports on change in AF. However, the change in conventional DXA trunk fat ( $\Delta$ trunk fat) failed to show a significant correlation with  $\Delta$ WC even after adjustment for age and total body fat. When we adjusted DXA ROI instead, the correlation with  $\Delta$ WC turned out to be significant. The change in a DXA ROI ( $\Delta$ ROI) revealed an association with WC and WHtR ( $\gamma = 0.39, 0.37$ , respectively,  $p < 0.05$ ). WC was a better surrogate than WHR, which was only useful at baseline but not after weight loss in this study and in a previous study.<sup>25</sup> The usefulness of  $\Delta$ WC from DXA ROI in this study corresponds well with the result:  $\Delta$ WC was associated with  $\Delta$ VAT by MRI ( $\gamma = 0.80, p < 0.01$ ;  $\gamma = 0.41, p < 0.05$ , respectively) reported in a previous study.<sup>26</sup> We assume that the DXA ROI is more abdomen-specific and therefore a more valid index of abdominal adiposity than DXA trunk fat, however, more research is needed in this area.

Moreover, it would appear that BMI is a good surrogate for AF after weight loss. It showed the highest correlation with DXA trunk fat and DXA ROI at follow-up and with changes.  $\Delta$ BMI was suggested as one of the best index of  $\Delta$ VAT by MRI ( $\gamma = 0.85, p < 0.01$ ) in obese-women<sup>27</sup> where  $\Delta$ BMI was better than  $\Delta$ DXA ROI (lumbar vertebra 2 - 4,  $\gamma = 0.73, p < 0.01$ ) for  $\Delta$ VAT by MRI<sup>26</sup>. However, it should be noted that DXA estimates fat not adipose tissue which is similar but not identical.<sup>27</sup>

This study suggests that WC could be a useful predictor of AF both cross-sectionally and with weight loss induced changes. BMI could also be useful just after weight-loss. Future studies with a larger sample size and advanced imaging technique, such as CT or MRI, that can discriminate these data are necessary to further our understanding.

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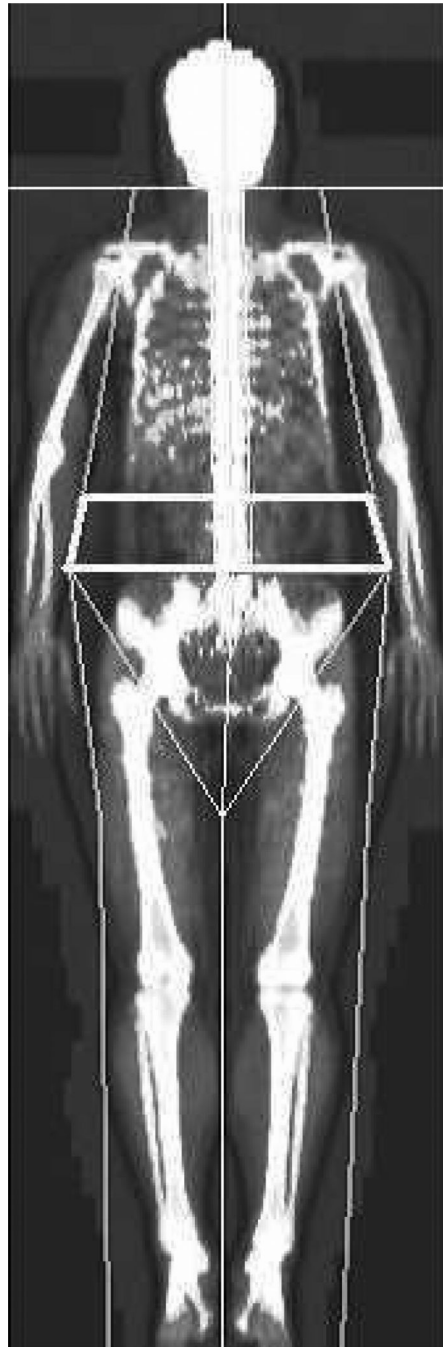
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**Figure 1.**  
DXA planogram demonstrating DXA Region Of Interest (ROI): the upper edge of the second lumbar vertebra to above the iliac crest.



**Table 1**

## Ingredients of the Herbal Diet Formula (Slim-Diet)

Herb	Amount (g)	Herb	Amount (g)
<i>Ginseng Radix</i>	2	<i>Rehmanniae Radix Preparat</i>	12
<i>Citri Pericarpium</i>	8	<i>Lycii Fructus</i>	8
<i>Mori Folium</i>	12	<i>Angelicae gigantis Radix</i>	4
<i>Coicis Semen</i>	12	<i>Cnidii Rhizoma</i>	4
<i>Poria</i>	8	<i>Benincasae Semen</i>	4
<i>Polyporus</i>	8	<i>Mori Ramulus</i>	4
<i>Acanthopanax Cortex</i>	4	<i>Pini Folium</i>	4
<i>Eucommiae Cortex</i>	4	<b>TOTAL</b>	98

**Table 2**

## Anthropometric Characteristics of Subjects (n=38)

	Baseline	Follow-up	Change
Age (years)	31.6±6.14		
Height (cm)	160±5.34		
Weight (kg)	81.3±11.5	78.4±10.9	- 2.91±2.36*
BMI (kg/m <sup>2</sup> )	31.7±3.50	30.6±3.36	- 1.13±0.89*
Waist circumference (cm)	94.4±7.05	91.4±7.20	- 3.07±4.05*
Hip circumference (cm)	112±7.02	112±17.0	- 0.45±17.0
Waist-to-hip ratio	0.84±0.03	0.83±0.08	- 0.01±0.08
Waist-to-height ratio	0.59±0.04	0.57±0.04	- 0.02±0.03*

Values are mean ± SD

\* Decreased significantly at  $p < 0.001$ (paired T test).

**Table 3**

Body composition and abdominal fat measures by DXA (n=38)

	Baseline	Follow-up	change	<i>p</i> -value
FFM (kg)	45.9±6.18	45.1±6.00	- 0.79±1.34	0.001
BF (kg)	34.5±6.63	32.9±6.64	- 1.63±1.69	0.000
Fat (%)	42.8±3.71	42.0±3.65	- 0.76±1.48	0.003
BMC (kg)	2.77±0.38	2.74±0.33	- 0.03±0.15	0.298
Trunk fat (kg)	18.7±3.38	17.8±3.46	- 0.90±1.17	0.000
ROI (kg, upper L2- upper iliac)	3.15±6.74	2.98±6.81	-0.17±0.21	0.000

Values are mean ± SD; \*, Decreased significantly at  $p < 0.001$  (paired T test); FFM, fat free mass (DXA weight – body fat); BF, body fat; BMC, bone mineral content; ROI, region of interest (L2-upper iliac).

**Table 4**

Associations between DXA and Anthropometrics at baseline and follow-up of 6 week weight loss program (n=38)

		<b>BMI</b>	<b>WC</b>	<b>WHR</b>	<b>WHtR</b>
Trunk fat (DXA)	Baseline	0.91**	0.92**	0.40**	0.80**
	Follow-up	0.84**	0.80**	0.23	0.74**
ROI (DXA)	Baseline	0.87**	0.91**	0.46**	0.82**
	Follow-up	0.88**	0.84**	0.23	0.82**

Values are Pearson's correlation coefficient

\*, significant at 0.05 level (*p*-value)

BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; ROI, region of interest (upper L2-upper iliac).

\*\* significant at the 0.01 level (*p*-value)

**Table 5**

Associations between change in DXA measures and Anthropometry during weight-loss (n=38)

	$\Delta$ BMI	$\Delta$ WC	$\Delta$ WHR	$\Delta$ WHtR
$\Delta$ Trunk fat (DXA)	0.44**	0.20	- 0.32	0.19
$\Delta$ ROI (DXA)	0.63**	0.39*	- 0.21	0.37*

Values are Pearson's correlation coefficient

BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; ROI, region of interest (L2-upper iliac).

\*\* significant at the 0.01 level (*p*-value)\* significant at 0.05 level (*p*-value)

**Table 6**

Multiple-regression analysis DXA derived Abdominal Fat (DXA ROI, L2-upper iliac) prediction models

	<b>Independent variable</b>	<b>Regression coefficient (<math>\pm</math>SE)</b>	<b><math>\gamma^2</math></b>	<b><i>p</i></b>
Baseline	WC	0.087(0.007)	82.9%	<0.001
Follow-up	BMI	0.114(0.024)	77.1%	<0.001
	WC	0.038(0.012)	82.5%	0.003
Change	BMI	1.53(0.314)	40.3%	<0.001