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DENSITOMETRIC TO ANTHROPOMETRIC INDEXES OF VISCERAL OBESITY RELATIONS

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Summary: Central obesity index (COI) is useful method for assessing body fat distribution. It was used to divide 110 women according to their body fat distribution in 3 groups: 1st group with normal body fat distribution and COI<0.8; 2nd group with moderate visceral obesity and 0.8<COI<1.0 and the 3rd group with extreme visceral obesity and COI>1.0. Densitometric indexes (DI) of visceral obesity were determined: COI = android/gynoid fat mass % (A%/G%), arm+leg/trunk fat mass (AL/T), legs/trunk (L/TR), legs/total (L/T) and trunk/total fat mass (TR/T), and anthropometric indexes (AI) of visceral obesity: waist/hip ratio (WHR), waist/thigh ratio (WTR), sagittal diameter (SAD), SAD/waist ratio (SAD/W), SAD/thigh ratio (SAD/T), SAD/hip ratio (SAD/H) and SAD/height ratio (SAD/HT). BMI, body weight (BW), total fat mass, G and SAD/W were not different between the 2nd and the 3rd group. W, WHR, WTR, SAD, SAD/T, SAD/H, SAD/HT values were significantly different among the groups (p<0.0001). AL/T values in the 1st group 1.17±0.17, in the 2nd group 0.93±0.14 and 3rd group 0.69±0.08, and the correspondent values of other DI L/TR 0.89±0.14, 0.73±0.11 and 0.53±0.08; L/T 0.43±0.04, 0.37±0.04 and 0.29±0.03; and TR/T 0.45±0.04, 0.51±0.04 and 0.58±0.03 were highly significantly different among the groups (p<0.0001). COI correlated highly significantly with DI and AI, and A (p<0.0001), but not with G, and SAD/W. Other DI and AI correlated highly significantly with A, but not with G.

Extreme visceral obese women were characterized with significantly highest values of DI and AI indexes, except BMI, BW, SD/W, total and G fat mass. They were confirmed as very useful indicators of visceral obesity.

Key words: Densitometric indexes; Anthropometric indexes; Visceral obesity; Women

Introduction

Dual-energy X-ray absorptiometry (DXA) is a sensitive technique of body composition assessment, which measures whole and segmental body fat and lean body mass. Today DXA is considered to be the gold standard for assessment of bone health and body composition. Body composition is the ratio of lean body mass to fat body mass. Using DXA to determine the proportion of lean body mass (muscle) versus total body fat is a valuable clinical tool in the management of long-term health and fitness (Brownbill et al. 2005). DXA enables determination of body fat distribution as well as central obesity index (COI) values. Body fat distribution is simply determined with DXA by the relationship of the regional (segmental) fat compartments. COI indicated android to gynoid fat mass percentage ratio, which is in a positive relation with the abdominal, visceral (central) obesity, and the metabolic syndrome. Densitometric indexes of visceral obesity determine the relationship between central (visceral) to peripheral body fat compartments.

Body mass index (BMI) has been proposed as a simple and valid measure for monitoring of fatness. BMI does not provide information on body fat distribution. Anthropometric measurements, mainly skinfold thickness, circumference and diameter measurements, have been used for decades to classify different types of fat distribution, usually on the basis of the different ratios. In clinical practice abdominal adiposity has been estimated using indirect anthropometric methods such as the waist to hip ratio (WHR) or waist circumference, waist to thigh ratio (WTR) and sagital abdominal diameter (SAD) (Ball et al. 2003). Anthropometric estimates are an acceptable measure of intraabdominal fat and therefore disease risk. Densitometric indexes (DI) and anthropometric indexes (AI) as well as COI can monitor the regional fat distribution (e.g., visceral vs. subcutaneous), which is clinically useful in relation to cardiovascular disease risk, glucose metabolism, and insulin resistance (Dencker et al. 2007).

The aim of the study was to determine the relationship between COI and DI as well as AI of visceral obesity, and also with BMI, body weight (BW) and total fat mass (TFM). DXA assessment of body fat distribution was performed and the association of COI values with DI and AI was determined.

Materials and methods

DXA examination was performed in 110 healthy women with mean age 51.98±13.19 yr, BMI 28.21±4.91 kg/m2 and BW 71.74±12.37 kg. The examinees were divided in 3 groups according to their COI values: 1st group with mean COI value <0.8; 2nd group 0.8<COI<1.0; and the 3rd group COI>1.0. The 1st group consisted of 24 patients, the 2nd group - 51, the 3rd group – 35.

DXA assessment was performed with Lunar DPX-NT system which uses encore 10.x Windows-XP Professional OS computers. For body composition measurements, a scan of the entire body was performed. Total fat mass (TFM) was determined as well as regional fat masses (FM) and FM%: arm FM, leg FM, truncal FM (TR), android FM (A), gynoid FM (G). DXA assessment of the central abdominal fat, android fat mass (A) was measured automatically from the upper border of vertebrae L2 to the lower border of L4. Gynoid fat mass was measured automatically on the upper thigh. Densitometric indexes of visceral obesity were determined: central obesity index as a ratio of the percentages of android to gynoid FM, COI = android/gynoid FM% (A%/G%), arm+leg/trunk fat mass ratio (AL/T), legs/trunk (L/TR), legs/total (L/T) and trunk/total fat mass ratio (TR/T).

BMI was defined as the body weight (BW) in kilograms, divided by the square of the height in meters (kg/m2). Body height was measured by a wall stadiometer in barefoot subjects, and body weight was measured by a digital scale.

Body fat distribution was assessed using anthropometric indexes of visceral obesity: waist/hip circumference ratio (WHR), waist/thigh circumference ratio (WTR), sagittal abdominal diameter (SAD), SAD/waist circumference ratio (SAD/W), SAD/thigh circumference ratio (SAD/T), SAD/hip circumference ratio (SAD/H) and SAD/height ratio (SAD/HT). Waist circumference was measured at the midpoint between the lower border of the rib cage and the iliac crest. SAD was measured in supine position at the umbilical level.

Statistical analyses were performed using the statistical software program SPSS for Windows, version 14.0. $P<0.05$ values were considered significant. Each parameter was presented as the mean ± SD. Differences among groups were evaluated by performing an analysis of variance (ANOVA) for normally distributed parameters or by Kruskal-Wallis test for non-parametric data. Correlation coefficients were determined by Pearson's product moment.

Results

Anthropometric indexes of visceral obesity, presented in Table 1 are highly significantly different between the groups ($p<0.0001$), except for SD/W ($p<0.014$).

Table 1. Anthropometric indexes of visceral obesity

Variable	Group 1	Group 2	Group 3
Waist circumference (cm)	78.74±5.43	93.99±9.29	101.59±9.39
Waist/hip ratio	0.82±0.04	0.89±0.06	1±0.08
Waist/thigh ratio	1.37±0.07	1.47±0.11	1.67±0.14
Sagittal abdominal diameter (cm)	19.94±1.97	24.22±3.16	26.97±3.37
SAD/waist circumference ratio	0.25±0.02	0.26±0.02	0.26±0.015
SAD/thigh circumference ratio	0.35±0.03	0.38±0.04	0.44±0.05
SAD/hip circumference ratio	0.21±0.02	0.23±0.023	0.27±0.03
SAD/height ratio	0.12±0.01	0.15±0.02	0.17±0.02

Densitometric indexes of visceral obesity, presented in Table 2 are all highly significantly different between the groups ($p<0.0001$).

Table 2. Densitometric indexes of visceral obesity

Variable	Group 1	Group 2	Group 3
Central obesity index	0.63±0.12	0.91±0.05	1.07±0.07
Arm+Leg/Trunk fat mass	1.16±0.17	0.93±0.14	0.69±0.08
Leg/Trunk fat mass	2.05±0.18	1.89±0.13	1.73±0.12
Leg/Total fat mass	0.89±0.14	0.73±0.11	0.53±0.08
Trunk/Total fat mass	0.45±0.04	0.51±0.04	0.58±0.03

Android fat mass percent values presented in Table 3 are significantly different between the groups ($p<0.0001$). COI values progressive increase is associated with android fat mass % but not gynoid fat mass % values progressive increase. The 3rd group have significantly lower gynoid fat mass % values compared to the 2nd group ($p<0.001$).

Table 3. Android and gynoid fat mass values in dependence on COI levels

Variable (%)	Group 1	Group 2	Group 3
Android fat mass	29.78±8.33	48.75±5.15	53.05±3.61
Gynoid fat mass	46.74±6.19	53.31±4.81	49.62±4.59
Total fat mass	32.49±6.49	44.21±5.44	44.4±4.22

COI values correlate highly significantly positively with densitometric and anthropometric indexes of visceral obesity ($p<0.0001$).

Android fat mass % correlates highly significantly positively with COI ($p<0.0001$), but gynoid fat mass % correlates with very low significance ($p<0.029$) (Figures 1 and 2).

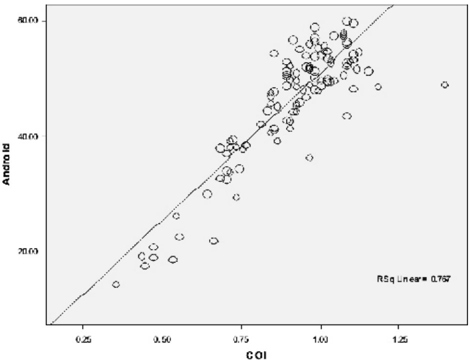

Figure 1. COI correlation with and roid fat mass

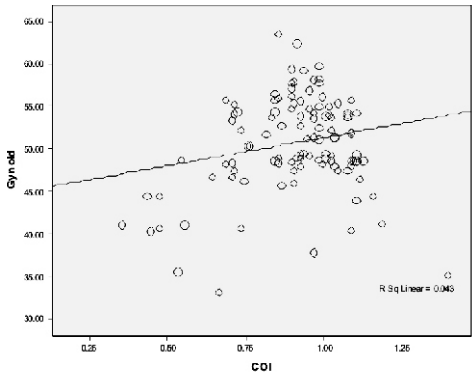

Figure 2. COI correlation with gynoid fat mass %

BMI, BW and TFM values and their dependence on COI values are presented in Table 4. Their values in the 1st group are significantly lower compared to the 2nd and the 3rd group ($p<0.0001$), but there is no significant difference between the 2nd and the 3rd group.

Table 4. BMI, BW, TFM values in dependence on COI levels

Variable	Group 1	Group 2	Group 3
BMI (kg/m^2)	22.54±2.27	29.16±4.47	30.7±3.75
BW (kg)	58.91±6.66	74.85±12.08	76.01±9.84
TFM (kg)	19.11±5.43	32.97±8.64	33.49±6.32

Discussion

The core abnormality of metabolic syndrome is the increased body weight, and particularly . Obesity and body fat distribution are known as risk factors for cardiovascular disease. Body composition, including fat mass, body fat distribution and muscle mass, gradually change with aging, even if the body weight and BMI remain unchanged (Srrensen et al. 2001; Dionne et al. 2000). BMI is used as a practical marker to assess obesity, and it is closely correlated with the degree of body fat in most settings. BMI does not quantitate body composition, and it does not show the difference between excess fat and muscle (Dencker et al. 2007). BMI cannot provide accurate information about fat distribution.

The most accurate anatomical methods of intra-abdominal fat measurement are CT, MRI and DXA. Measurement of intra-abdominal fat by MRI was highly correlated with the central abdominal fat measured by DXA (Kamel et al. 1999). A strong correlation existed between DXA and CT values for total abdominal fat. DXA is a good alternative to CT for predicting total abdominal fat in the elderly population (Kim et al. 2007). Excess body fat in the abdominal region is referred to as android obesity, and it is associated with increased risk for cardiovascular disease. DXA measurements of fat distribution may be useful for studies of obesity-associated disease risk (Ley et al. 1992). Individuals with an "apple", or abdominal fat distribution pattern (upper body) are at a substantially higher risk for developing cardiovascular and metabolic diseases compared with those with a "pear", or lower body fat distribution pattern (hips, thighs and buttocks). Most females store fat in the gynoid pattern while most males store fat in the android pattern (Panotopoulos et al. 1996). An android fat pattern is attributed to overweight females and, even more pronounced, to the weight cyclers (Horejsi et al. 2004; Wallner et al. 2004). Android obesity, which is predominantly abdominal, is more predictive of adipose-related comorbidities than gynecoid obesity, which has a relatively peripheral (gluteal) distribution. Because of that, effective methods for assessing visceral fat are important to investigate its role for the increased health risks in obesity (Snijder et al. 2002; Toth et al. 2000; Srrensen et al. 2001; Dionne et al. 2000).

DXA determines total and regional body composition. DXA is considered to be a gold standard because of its reliability, precision, and the fact that it is based on a three-compartment model. DXA method determines total body fat mass and fat mass percent, bone mass and lean mass, and separately their regional values for the arms, legs, head and trunk (which includes ribs, pelvis, thoracic spine, and lumbar spine). DXA is also used to quantify abdominal fat mass (Lear et al. 2006).

In addition to general obesity, the distribution of body fat is independently associated with the metabolic syndrome. Our findings suggest that DXA measurements of fat distribution may be useful in studies related to obesity-associated disease risk. DXA enables precise, accurate body composition and body fat distribution assessment and it was shown that BMI increase was associated with more pronounced abdominal obesity, indicating substantially higher risk for development of cardiovascular and metabolic diseases (Šubeska-Stratrova, 2010).

COI is an indicator of central, abdominal obesity, which is the main characteristic of the metabolic syndrome. COI is calculated as a ratio of the percentage of predominantly visceral android abdominal fat tissue mass, and the percentage of gynoid fat tissue mass, which is only peripheral fat tissue mass. In this study COI correlated significantly positively with G% ($p<0.029$), but it correlated highly significantly positively with A% ($p<0.0001$). Higher significance of the COI correlation with A% was detected in comparison with the correspondent gynoid values, confirming COI positive association with central, abdominal fat mass, and abdominal fat distribution.

No significant difference of BMI, BW and TFM between the 2nd and the 3rd group indicates that progressive COI value increase is not associated with their progressive increase in the 3rd group compared to the 2nd group. Patients with extreme visceral obesity and highest values of the central body fat distribution anthropometric and densitometric indexes and highest COI values are not characterized with highest BMI, BW and TFM values.

DXA investigates the normal and pathological topography of fat distribution to reveal the possible correlation with metabolic disorders. The trunk fat is a deleterious risk factor for cardiovascular disease (insulin resistance and dyslipidemia) in women. Leg fat mass is associated with a more favorable metabolic profile after adjustment for risk attributable to central adiposity, whereas arm fat mass had no such association (Tatsukawa et al. 2000; Christou et al. 2004). Increased leg fat mass appears to be favorably associated with cardiovascular disease risk factors after adjusting for central adiposity (Williams et al. 1997). Fat tissue in legs has a protective effect against the metabolic disorders. The apparent protective effect of increased leg fat mass is simply indicative of a propensity to store fat subcutaneously. Peripheral fat tissue has a negative association with metabolic dysfunction. Among densitometric indexes performed in this study, AL/T, L/TR and L/T indicate the relationship between the peripheral to central fat compartments, and TR/T indicate relationship between the central to total fat, and enable body fat distribution determination.

Kamel et al. 2000, investigated the usefulness of anthropometry and DXA in predicting intra-abdominal fat in obese men and women. In obese women, DXA, waist circumference and WHR were equally well correlated with intra-abdominal fat. Anthropometry and DXA were equally useful in obese women (Dolan et al. 2007).

Some simple and safe anthropometric measurements such as waist circumference, sagittal abdominal diameter, WHR, and abdominal skinfold thickness could be useful in the estimation of deep-abdominal fat deposition and they can be used, instead of total and visceral adipose tissue area as assessed by CT, when studying associations between adipose tissue and metabolic parameters (Ellis, 2000), and in the assessment of the cardiovascular-disease risk (Broom, 2006). The different sets of anthropometric measures were usually a combination of circumferences, skinfolds, diameters and their ratios.

Fat distribution is usually assessed in the population by the waist to hip circumference ratio (WHR). Abdominal deposition of fat assessed by WHR may be of strong clinical value for predicting high risk of cardiovascular events (Schneider et al. 2007; Rhodes & O'Neil, 1997). A high WHR has to be a proxy measurement for an excess of intra-abdominal fat. A high WHR ratio would indicate a central fat distribution, a low WHR ratio would indicate peripheral fat distribution (Kahn, 1993). Waist/hip ratio and sagittal abdominal diameter are considered representative measurements of intraabdominal adipose tissue. There is a good correlation between waist/hip ratio, sagittal abdominal diameter and computed tomography-measured visceral adipose tissue. Abdominal fat ditribution is most often defined by a WHR>0.95 in men and WHR>0.8 in women.

It is now recognized that truncal obesity, as measured by either the waist circumference or the waist-hip ratio, is a strong risk factor for an array of metabolic problems termed 'metabolic syndrome' (Penington & Morrison, 2007). Waist-to-hip ratio was a better predictor of dyslipidemia than waist circumference, although the latter showed better discriminating power to detect hypertriglyceridemia (Ferreira et al. 2006). The WHR and waist circumference are independently associated with risk of coronary heart disease in women (Kahn et al. 1996, 1998). Waist/hip and the waist/thigh ratios were more strongly related to the amount of intra-abdominal fat assessed by computed tomography than to the amount of subcutaneous abdominal fat. The 'best' index of centralised fat in children is therefore, the waist/thigh circumference ratio, the same one that has been suggested for adults (Mueller et al. 1989). Waist/thigh ratios were generally more strongly and more consistently related to risk factors than waist/hip ratios (Seidell et al. 1992). Waist-to-thigh circumference ratio proved to be the strongest correlate of serum lipids compared with other measures of fat distribution (Seidell et al. 1988). Waist/thigh and waist circumference alone were stronger correlates of cardiovascular risk factors compared to waist/hip ratio. Intra-abdominal fat volume was significantly predicted by only one variable, sagittal abdominal diameter, while subcutaneous fat volume was predicted by hip and thigh circumferences (Keller et al. 1999). The waist circumference and the abdominal sagittal diameter are better correlates of abdominal visceral adipose tissue accumulation than the commonly used waist-to-hip ratio. Sagittal abdominal diameter might be better correlated with intrabdominal fat, than the more commonly used waist-to-hip ratio, which may be more affected by subcutaneous abdominal fat (Kahn, 1993). Therefore, the waist circumference, and the abdominal sagittal diameter are the anthropometric indexes preferred over the WHR to estimate the amount of abdominal visceral fat and related cardiovascular risk profile, and are more closely related to the metabolic variables (Kunesova et al. 1995). These findings suggest that the waist circumference or the abdominal sagittal diameter, rather than the WHR, should be used as indexes of abdominal visceral adipose tissue deposition and in the assessment of cardiovascular risk. It is suggested from these data that waist circumference values above approximately 100cm, or abdominal sagittal diameter values > 25cm are most likely to be associated with potentially "atherogenic" metabolic disturbances. Waist circumference, measured with a tape measure at level midway between the lowest ribs and hip bone, should ideally not exceed 80cm for women or 94 cm for men. Below these figures, there is no need for weight loss.

Extreme visceral obese women were characterized with significantly highest values of the assessed DI and AI indexes in this study, except BMI, BW, SAD/W, total and G fat mass. These DI and AI were confirmed as very useful indicators of visceral obesity. These DI (AL/T, L/TR, L/T, TR/T) as well as AI of visceral obesity (WHR, WTR, SAD, SAD/T, SAD/H, SAD/HT) except SAD/W, correlated highly significantly positively with COI and were confirmed as a valuable tool for discovering visceral obesity.

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POVEZANOST DENZITOMETRIJSKIH SA ANTROPOMETRIJSKIM INDEKSIMA VISCERALNE GOJAZNOSTI

Izvod

Indeks centralne gojaznosti (COI) je koristan metod za procenu telesne distribucije masti. Na osnovu vrednosti ovog indeksa, grupa od 110 žena bila je podeljena na 3 grupe: grupa 1 sa normalnom telesnom distribucijom i COI<0,8; grupa 2 sa umerenom visceralnom gojaznošću i 0,8<COI<1,0 i grupa 3 sa ekstremnom visceralnom gojaznošću i COI>1,0. Određeni su denzitometrijski indeksi (DI) visceralne gojaznosti: COI = androidna/ginoidna masna masa % (A%/G%), ruka+noga/trup masna masa (AL/T), noga/trup (L/TR), noga/ukupna (L/T) i trup/ukupna masna masa (TR/T), kao i antropometrijski indeksi (AI) visceralne gojaznosti: struk/kuk (WHR), struk/natkolenica (WTR), sagitalni abdominalni dijametar (SAD), SAD/struk (SAD/W), SAD/natkolenica (SAD/T), SAD/kuk (SAD/H) i SAD/visina (SAD/HT). BMI, telesna masa (BW), ukupna i G masna masa i SAD/W nisu se razlikovale između grupe 2 i grupe 3. Vrednosti W, WHR, WTR, SAD, SAD/T, SAD/H, SAD/HT signifikantno su se razlikovale između grupa (p<0.0001). Vrednosti AL/T (grupa 1: 1,17±0,17, grupa 2: 0,93±0,14, i grupa 3: 0,69±0,08), L/TR (grupa 1: 0,89±0,14, grupa 2: 0,73±0,11 i grupa 3: 0,53±0,08), L/T (grupa 1: 0,43±0,04, grupa 2: 0,37±0,04 i grupa 3: 0,29±0,03) i TR/T (grupa 1: 0,45±0,04, grupa 2: 0,51±0,04 i grupa 3:

0,58±0,03) signifikantno su se razlikovale između grupa (p<0,0001). COI je korelirao visoko signifikantno sa DI, AI i A (p<0,0001), ali ne i sa G i SD/W. Ostali DI i AI su korelirali visoko signifikantno sa A, dok nisu pokazali značajnu korelaciju sa G. Ekstremno visceralno gojazne žene karakterisale su se najvećim vrednostima DI i AI indeksa, osim BMI, BW, SAD/W, ukupne i G masne mase. Oni su bili potvrđeni kao veoma korisni indikatori visceralne gojaznosti.

Ključne reči: Denzitometrijski indeksi; Antropometrijski indeksi; Visceralna gojaznost; Žene