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Visceral Fat Area Evaluation by Computed Tomography Correlates with Visceral Fat Volume

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Abstract

In Japan, the measurement of abdominal circumference is commonly used in diagnosis of visceral fat accumulation. It is also recommended that visceral fat at the umbilical level be measured using CT scans. If CT is used to measure the visceral fat area, we do not have to consider the possibility of measurement error due to subcutaneous fat. However, it is unknown whether the visceral fat area measurement by CT reflects the visceral fat volume of the entire abdomen.

We examined the correlation between the visceral fat area at the umbilical level and the visceral fat volume of the entire abdomen using CT images taken from the diaphragm to the pubic bone.

The results showed that there was a very high correlation between the visceral fat area and the visceral fat volume. The correlation was not affected by gender differences, old age or whether visceral fat was accumulated or not.

Therefore, we concluded that it is possible to estimate the visceral fat volume of the entire abdomen by measuring the visceral fat area at the umbilical level.

Keywords: visceral fat accumulation, CT scan, metabolic syndrome, obesity

1. Introduction

Recently, many developed and civilized countries have addressed the issue of lifestyle-related diseases such as cardiovascular and cerebrovascular disorders and diabetes, and these diseases have been associated with obesity. Many researchers have worked toward identifying the risk factors, and the cluster of these risk factors is called the metabolic syndrome. The major mechanisms of the metabolic syndrome are thought to be insulin resistance syndrome, visceral fat syndrome and inflammation; other factors include diet, smoking, physical inactivity, aging, socioeconomic factors, hormonal imbalance, and exposure to environmental pollutants. (DeFronzo & Ferrannini, 1991; Fujioka, Matsuzawa, Tokunaga, & Tarui, 1987; Lemieux et al., 2000) Traditionally, the body mass index (BMI) has been used as a measure of abdominal obesity; however, in recent years, more and more studies use measures of visceral fat.

Accumulation of visceral fat has also been associated with diseases other than vascular disorders and diabetes. A meta-analysis done by Hampel et al. (2005) showed that obese people with BMI of ≥ 25 kg/m2 are more likely to develop esophageal adenocarcinoma. Many esophageal adenocarcinomas arise from Barrett's epithelium, and Barrett's epithelium is believed to be associated with the area of visceral fat rather than BMI. Giovannucci et al. (1995) reported that visceral obesity significantly increases the risk of colon cancer (El-Serag, Kvapil, Hacken-Bitar, & Kramer, 2005).

Visceral fat is known to cause many diseases, but there are various ways to assess its volume; typical ways of assessment include assessment of obesity by weight (and BMI), estimation of visceral fat volume by measurement of waist circumference, and analysis by abdominal CT at the level of the umbilicus.

As the number of obese people in Japan increases, there are more who are concerned about their visceral obesity and metabolic syndrome, and who work toward or are interested in losing weight.

The method of visceral fat measurement using CT scan was developed by Tokunaga et al. (1983), and Matuzawa et al. (2002) proved the usefulness of setting the reference value of visceral fat area to 100 cm2.

Table 1 shows the criteria for the metabolic syndrome and obesity assessment methods presented by various organizations worldwide. As shown in this table, only in Japan is obesity assessed using CT scans. According to a study by Mizui et al. (2012), the detection rate of visceral fat accumulation with a visceral fat area of > 100 cm2 by CT was about twice as high in men than in women. When visceral fat accumulation was diagnosed based on waist circumference measurement, in men with a waist circumference of ≥ 85 cm and women ≥ 90 cm, approximately 2.4 times more women were diagnosed as having visceral fat accumulation with a visceral fat area > 100 cm2 compared to men. The reason for this was explained that since more Japanese women have subcutaneous obesity rather than visceral obesity, measurement of only the waist circumference would decrease the sensitivity of visceral fat assessment. (Eguchi et al., 2007).

Table 1. Diagnostic standard for the metabolic syndrome

	WHO(1999)	National Cholesterol Education Program Guidelines for Treatment of Hyperlipidemia (2001)	International Diabetes Federation: IDF (2005)	Japan (2005)
Definition	Diabetes, impaired fasting glucose, impaired fluscose tolerance, and insulin resistance. All the above is required, together with two or more the following:	Three or more of the following:	Central obesity a requirmnet, together with two or more of the following:	Central obesity a requirement, together with two or more of the following (triglycerides and/or HDL-C are considered as one component)
Obesity	Waist-hip ratio Men: >0.90 Women: >0.85 Or BMI > 30 kg/m^2	Abdominal obesity Waist circumference: Men: ≥ 102 cm Women: ≥ 88 cm	Men: ≥ 85 cm Women: ≥ 90 cm	Men: ≥ 85 cm Women: ≥ 90 cm Or visceral fat area ≥ 100 cm^2
Triglycerides (mg/dl) HDL-C (mg/dl)	≥ 150 Men: < 35 Women: < 39	≥ 150 Men: < 40 Women: < 50	≥ 150 (counted even when under treatment) Men: < 40 Women: < 50 (counted even when under treatment)	≥ 150 (counted even when under treatment) < 40 (counted even when under treatment)
Blood pressure (mmHg)	≥ 140/90	≥ 130/85	≥ 130/85 (counted even when under treatment)	≥130/85 (counted even when under treatment)
Urinary albumin	Urinary albumin excretion rate ≥ 20 μg/min Or albumin:creatinine ratio ≥ 30 mg/g			
Fasting glucose (mg/dl)	In addition to impaired fasting glucose, one of the above abnormalities of glucose tolerance is required.	≥ 110	≥ 100 Or type 2 diabetes	≥ 110 (counted even when under treatment)

In 2005, the International Diabetes Federation (IDF) proposed some criteria for the metabolic syndrome which required assessment of abdominal obesity by measurement of waist circumference; however, the American Heart Association (AHA) and the National Heart, Lung, and Blood Institute (NHLBI) issued a joint statement that the diagnostic criteria of the National Cholesterol Education Program (NCEP) was better than the IDF criteria. The NCEP guidelines do include the diagnostic criteria for abdominal obesity, but the diagnosis of abdominal obesity is not a requirement. (Expert Panel on Detection, E. 2001) This reason is presumed to be that waist circumference measurements exceeding the reference values do not always reflect visceral fat accumulation (Alberti, Zimmet, & Shaw, 2005). In other studies, some researchers have reported that the definition of abdominal circumference in specific health check-ups, etc. should be reconsidered because the measurement method of abdominal circumference has problems. (Oka, R., et.al 2008) In addition to this, there are also attempts to measure visceral fat using MRI in recent years. Tanisawa et al. (2017) measured the visceral fat area in 143 Japanese men (30–79 years

old) using MRI and examined the relationship between plasma LECT 2 levels, various obesity indices and cardiorespiratory fitness (CRF). As a result, it was concluded that the visceral fat area was the strongest predictor of plasma LECT 2 and was a potential biomarker linking visceral fat obesity and dyslipidemia.

In Japan, the Japan Society for the Study of Obesity (JASSO) defines "obesity disease" as BMI ≥ 25 kg/m^2, visceral fat area ≥ 100 cm^2, and abdominal circumference ≥ 85 cm for men and ≥ 90 cm for women. The gold standard for assessing visceral fat is the method that uses CT imaging at the umbilical level to calculate the fat area. However, the definitive method of assessing visceral fat requires the CT scanning of the entire abdominal cavity and the evaluation of all visceral fat in this region; when obtaining CT images of the entire abdomen solely for assessing visceral fat, caution is required because CT scanning involves a relatively large amount of X-ray exposure. On the other hand, a scan taken only at the umbilical level, considering the imaging range, would involve radiation exposure of about 1/30 compared to the scanning of the entire abdomen; this test may be beneficial considering the risk of exposure to radiation, but it is unclear whether the visceral fat area at the umbilical level accurately reflects the total volume of visceral fat in the abdomen.

In this study, we will investigate the correlation between the visceral fat area at the umbilical level and the total volume of visceral fat in the abdomen using CT images of the entire abdomen that were taken during routine clinical practice, and discuss the appropriateness of measuring the visceral fat area using CT scanning.

2. Methods

2.1 Selection of Subjects

In this study, we used axial CT images from patients who underwent abdominal CT examination ordered by a doctor in clinical practice. For the data sampling procedure, we extracted CT images from the diaphragm to the pubic bone taken by helical scanners, which were obtained during those medical examinations. However, from these extracted images, we excluded cases of trauma pan scans and cases with obvious malignant tumors (including metastatic tumors) and cases with surgically treated scars and case of under the age of 18 years. Patients in this data did not undergo any intervention prior to or following this study.

All subjects in this study required an abdominal CT as judged by the doctor and underwent scanning done by radiological technologists under optimal imaging conditions. We did not limit the cases to those diagnosed as having no abnormalities. Therefore, there is a possibility that patients with abdominal disorders were included. The conditions used for scanning (tube voltage and tube current) were determined appropriately by radiological technologists. They determined the optimum dose according to patient body size that guaranteed the image quality necessary for diagnosis in all samples (image noise within ± 10 HU).

2.2 Sampling procedure

After obtaining the research permission of the Institutional Review Board of Suzuka Kaisei Hospital, we selected 7 days from the permitted research period. Of all the abdominal CT images taken on these days, we extracted 124 cases using a continuous sampling method. (These were images from the liver to the bladder.) Of these, we excluded one patient who was under the age of 18 years, 11 cases with surgically treated scars, two post-traumatic cases, and two cases with obvious malignancies and metastatic tumors. The final sample size was 108.

When collecting samples of CT images, we announced to the patients on bulletin boards and websites that their anonymized CT images might be used for this study. At the same time, we announced that it was possible for them to refuse to participate in this study. As a result, the number of subjects who refused to participate in this study was 0.

2.3 Analysis Procedure

Abdominal CT images of the above subjects were reconstructed with a slice thickness of 10 mm. We then selected images at the umbilical level, defined the region of interest in the abdominal cavity, and selected and calculated the area of visceral fat. Next, we measured the total volume of visceral fat from the CT slices of the abdomen. Lastly, we plotted these data with the area of visceral fat at the umbilical level on the x-axis and the volume of visceral fat of the entire abdomen on the y-axis, and analyzed the correlation between these two in all cases, and by male or female, presence or absence of visceral fat accumulation (visceral fat area at the umbilical level ≥ 100 cm2), and age ≥ 75 years or < 75 years.

2.4 Equipment Used

A CT scanner, Aquilion 64 manufactured by Toshiba Medical Systems Co., Ltd. was used, and analysis of visceral fat area and visceral fat volume was done with an analysis tool equipped in the instrument. We used Excel 2016 (Microsoft Corporation) for chart creation, and R (64 bit, ver. 2.3 - 0) for statistical analysis.

3. Results

In this study, the average age of the subjects was 70.3 ± 15.2 years with the age range of 20 to 95 years, and the male-to-female ratio was 59:49 (Table 2). Visceral fat accumulation was present in 40 cases and absent in 68 cases. Sixty-two cases were under 75 years of age, and 46 cases were 75 years old or older. The average area of visceral fat on a 10-mm slice at the umbilical level was 88.5 ± 49.5 cm2; the average total volume of visceral fat in the abdomen was 2186.6 ± 1255.2 ml. The correlation coefficient between the area of visceral fat at the umbilical level and the total volume of visceral fat in the abdomen was 0.95 (95% CI: 0.92-0.96) in all subjects. When the visceral fat area increased by 1 cm2, the visceral fat volume increased by 24.1 ml (Figure 1). Then, we calculated the correlation coefficients separately in males and females and compared them. The correlation coefficient between the area of visceral fat at the umbilical level and the total volume of visceral fat in the abdomen was 0.95 (95% CI: 0.93-0.97) in men and 0.93 (95% CI: 0.87-0.96) in women. There were no significant differences between the sexes in the rate of deviation from the approximate line of best fit (unpaired t-test P=0.24) (Figure 2). Next, we grouped the subjects into those with and without visceral fat area of > 100 cm^2, obtained the correlation coefficient for each group and compared them. The correlation coefficient between the area and the total volume of visceral fat was 0.89 (95% CI 0.82-0.93) in cases with visceral fat accumulation, and 0.89 (95% CI 0.80-0.94) in cases without visceral fat accumulation. There were no significant differences between those with and without visceral fat accumulation in the rate of deviation from the approximate line of best fit (unpaired t-test P=0.34) (Figure 3). Lastly, we grouped the subjects into those ≥ 75 years of age and < 75 years of age, and calculated and compared the correlation coefficients. The correlation coefficient between the area and the total volume of visceral fat was 0.97 (95% CI 0.94-0.98) in patients ≥ 75 years of age and 0.92 (95% CI 0.87-0.96) in patients < 75 years of age. There were no significant differences between the elderly and non-elderly in the rate of deviation from the approximate line of best fit (unpaired t-test P=0.41) (Figure 4).

Table 2. Subject features

Age		
	Average (y)	70.3±15.2
	Range (y)	20–95
Sex		(n=108)
	Male	59
	Female	49
Viseral Fat		
Area	Average (cm^2)	88.5±49.5
	Range (cm^2)	5.4-218.0
Volume	Average (cm^2)	2186.6±1255.2
	Range (cm^2)	200.9-5617.7
Elderly or Not (threshold 75y)		(n=108)
	< 75y	62
	≥75y	46

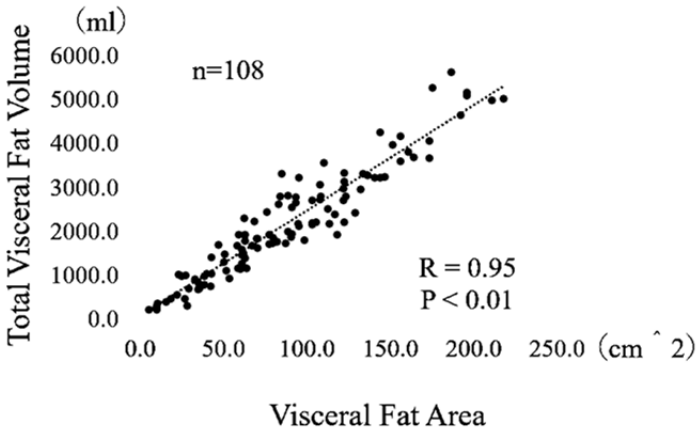

Figure 1. Relationship between visceral fat area and visceral fat volume

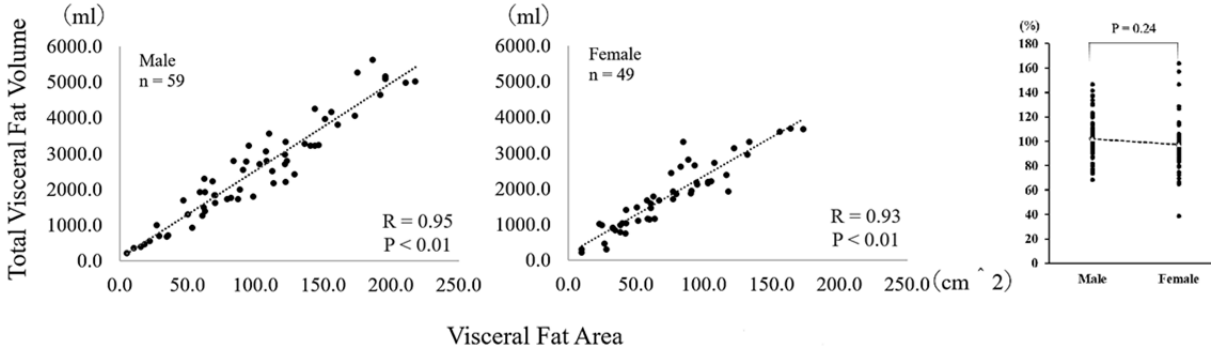

Figure 2. Relationship between visceral fat area and visceral fat volume; comparison of the rate of deviation from the approximate line of visceral fat area measurements (Male/Female)

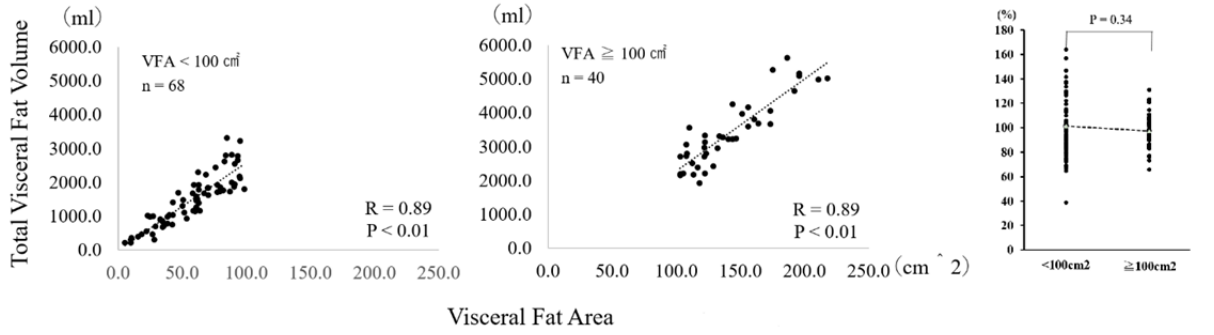

Figure 3. Relationship between visceral fat area and visceral fat volume; comparison of the rate of deviation from the approximate line of visceral fat area measurements (Comparison by presence or absence of visceral fat accumulation)

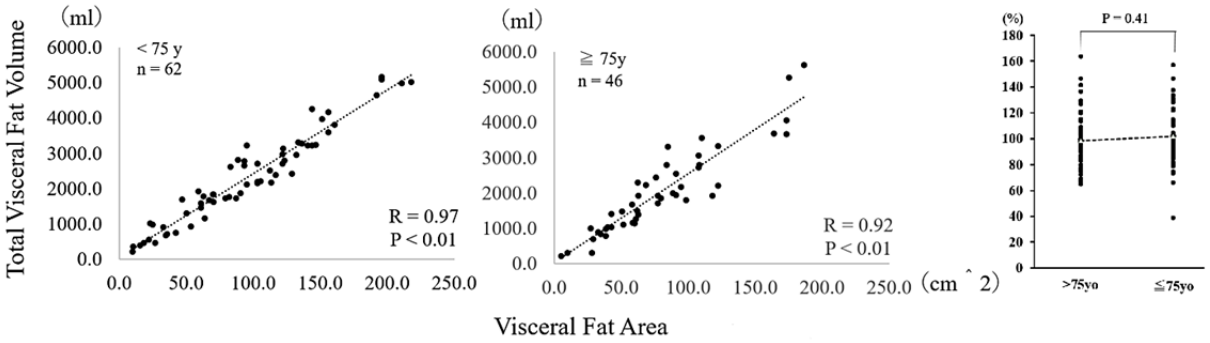

Figure 4. Relationship between visceral fat area and visceral fat volume; comparison of the rate of deviation from the approximate line of visceral fat area measurements (Comparison by elderly or not [threshold: 75 years old])

4. Discussion

The area of visceral fat at the umbilical level as assessed by CT showed a very high correlation with the total volume of visceral fat distributed within the abdomen (R = 0.95). This result shows the appropriateness of estimating the total volume of visceral fat in the abdomen using CT images at the umbilical level. Measuring the abdominal circumference using a tape measure is a convenient method but it lacks accuracy; CT scanning at the umbilical level is an effective way to solve this problem. The results of the analysis were not affected by gender differences or older age. However, differences due to the presence or absence of visceral fat accumulation may not be proved. This is due to the small sample size of cases with visceral fat accumulation in this study. A replication study with a larger number of samples is needed to demonstrate this point. However, this study showed that taking CT images at the umbilical level to analyze the area of visceral fat is very useful in assessing visceral obesity. Many researchers give negative consideration to the metabolic syndrome criteria proposed by many organizations that require measurement of abdominal circumference. We believe one of the reasons for this is the fact that measurement of abdominal circumference using a tape measure cannot accurately show the total volume of visceral fat within the abdominal cavity. However, analysis of visceral fat area at the umbilical level using CT can almost exactly show the total volume of visceral fat within the abdominal cavity. Since adipocytokine secretion is affected depending on the amount of visceral fat, it may be better to take CT images at the umbilical level and analyze the visceral fat, rather than to estimate the volume of visceral fat based on abdominal circumference measurement. Therefore, if measurement of abdominal circumference, which is currently a diagnostic criterion for the metabolic syndrome by various organizations, is replaced with the area of visceral fat as assessed by CT, a more accurate diagnosis can be provided to people at risk of the metabolic syndrome.

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Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

References

Alberti, K. G. M., Zimmet, P., & Shaw, J. (2005). The Metabolic Syndrome-A New Worldwide Definition. *The Lancet, 366*(9491), 1059.http://dx.doi.org/10.1016/S0140-6736(05)67402-8

DeFronzo, R. A., & Ferrannini, E. (1991). Insulin Resistance: A Multifaceted Syndrome Responsible for NIDDM, Obesity, Hypertension, Dyslipidemia, and Atherosclerotic Cardiovascular Disease. *Diabetes Care, 14*(3), 173-194.https://doi.org/10.2337/diacare.14.3.173

Eguchi, M., Tsuchihashi, K., Saitoh, S., Odawara, Y., Hirano, T., Nakata, T., ... & Shimamoto, K. (2007). Visceral Obesity in Japanese Patients with Metabolic Syndrome: Reappraisal of Diagnostic Criteria by CT Scan. *Hypertension Research, 30*(4), 315.

El-Serag, H. B., Kvapil, P., Hacken-Bitar, J., & Kramer, J. R. (2005). Abdominal Obesity and the Risk of Barrett's Esophagus. *The American Journal of Gastroenterology, 100*(10), 2151-2156. https://10.1111/j.1572-0241.2005.00251.x

Expert Panel on Detection, E. (2001). Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *Jama, 285*(19), 2486.

Fujioka, S., Matsuzawa, Y., Tokunaga, K., & Tarui, S. (1987). Contribution of Intra-Abdominal Fat Accumulation to the Impairment of Glucose and Lipid Metabolism in Human Obesity. *Metabolism, 36*(1), 54-59. https://doi.org/10.1016/0026-0495(87)90063-1

Giovannucci, E., Ascherio, A., Rimm, E. B., Colditz, G. A., Stampfer, M. J., & Willett, W. C. (1995). Physical Activity, Obesity, and Risk for Colon Cancer and Adenoma in Men. *Annals of Internal Medicine, 122*(5), 327-334.https://doi.org/10.7326/0003-4819-122-5-199503010-00002

Hampel, H., Abraham, N. S., & El-Serag, H. B. (2005). Meta-Analysis: Obesity and the Risk for Gastroesophageal Reflux Disease and Its Complications. *Annals of Internal Medicine, 143*(3), https://doi.org/199-211. 10.7326/0003-4819-143-3-200508020-00006

Lemieux, I., Pascot, A., Couillard, C., Lamarche, B., Tchernof, A., Alméras, N., ... & Nadeau, A. (2000). Hypertriglyceridemic Waist. *Circulation, 102*(2), 179-184. https://doi.org/10.1161/01.CIR.102.2.179

Matsuzawa, Y. (2002). New Criteria for 'Obesity Disease' in Japan: The Examination Committee of Criteria for 'Obesity Disease' in Japan, Japan Society for the Study of Obesity. *Circulation Journal: Official Journal of the Japanese Circulation Society, 66*(11), 987-992.http://doi.org/10.1253/circj.66.987

Mizui, M., Mizoguchi, Y., Yamada,T., Tanaka, I., & Senda, Y. (2012). The Comparison of Man and Woman in the Result of the Metabolic Syndrome CT Examination in Our Hospital. *The Journal of the Japanese Society of CT Screening, 19*, 94-101

Oka, R., Kobayashi, J., Yagi, K., Tanii, H., Miyamoto, S., Asano, A., ... & Katsuda, S. (2008). Reassessment of the Cutoff Values of Waist Circumference and Visceral Fat Area for Identifying Japanese Subjects at Risk for the Metabolic Syndrome. *Diabetes Research and Clinical Practice, 79*(3), 74-481. https://doi.org/10.1016/j.diabres.2007.10.016

Tanisawa, K., Taniguchi, H., Sun, X., Ito, T., Kawakami, R., Sakamoto, S., & Higuchi, M. (2017). Visceral fat area is a strong predictor of leukocyte cell-derived chemotaxin 2, a potential biomarker of dyslipidemia. *PloS one, 12*(3), e0173310. https://doi.org/10.1371/journal.pone.0173310

Tokunaga, K., Matsuzawa, Y., Ishikawa, K., & Tarui, S. (1983). A Novel Technique for the Determination of Body Fat by Computed Tomography. *Int J Obes., 7*(5), 437-45.