talenta PUBLISHER

JETROMI
Journal of Endocrinology, Tropical Medicine, and Infectiouse Disease
Journal homepage: https://jetromi.usu.ac.id

MEASUREMENT OF VISCERAL ADIPOSE TISSUE USING ABDOMEN CT SCAN AS A PREDICTOR OF TYPE 2 DIABETES MELLITUS

Duma Ratna Sari Nasution [*1], Netty Delvrita Lubis [2], Muhammad Aron Pase [2], Putri Chairani Eyanoer [3]

[1]*Department of Radiology, Adam Malik Hospital / Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia.*
[2]*Department of Internal Medicine, Adam Malik Hospital / Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia.*
[3]*Department of Community and Preventive Medicine, Adam Malik Hospital / Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia.*
[*]Corresponding Author: dumanasution.dn@gmail.com

ARTICLE INFO

Article history:
Received 15 March 2024
Revised 20 May 2024
Accepted 26 May 2024
Available online xxx

E-ISSN: 2686-0856
P-ISSN: 2686-0872

How to cite:
Duma Ratna Sari Nasution (2025). Measurement Of Visceral Adipose Tissue Using Abdomen Ct Scan As A Predictor Of Type 2 Diabetes Mellitus. Journal of Endocrinology, Tropical Medicine, an Infectiouse Disease, 7(1), 1-10. (make in IEEE style)

10.32734/jetromi.v7i1.15891

ABSTRACT

Background. Obesity is a condition where the BMI is ≥ 25 kg/m2. Deposition of visceral adipose tissue (VAT) in obese conditions is a predictor of the incidence of type 2 diabetes mellitus (T2DM). CT scan is an accurate measurement of VAT. A cut-off point value is needed to determine the stratification of VAT at risk for type 2 DM.
Methods. Cross-sectional study of patients undergoing CT scans of the abdominal area at the Radiology Installation of H. Adam Malik General Hospital, Medan in February 2024. Some of the data was taken from the Master of Clinical Medicine study in 2022. Data was collected in the form of examination BMI, waist circumference, DM risk score, and VAT volume in patients examined by abdominal CT scan at L4 level. The DM risk score was obtained using the ADA diabetes risk score questionnaire. VAT volume measurement using 3D segmentation tools.
Results. Of the 116 patients studied, the number of samples was 53,4% male and 46,6% female. High DM risk score proportion of 59,5 %. The most frequent DM risk score was 5. Spearman's correlation is used too. The best cut-off point between sensitivity 44.93% and specificity 80,85% is 1.311,9 cm3. The accuracy of CT scan as a predictor of type 2 DM is good (AUC 0.7). The positive predictive value (PPV) is 77,50%, and the negative predictive value (NPV) is 50%. The positive likelihood ratio value (LR +) is 2,34 and the negative likelihood ratio value (LR -) is 0,68.
Conclusion. VAT measurement using abdominal CT scan as a predictor of type 2 DM has good accuracy.

Keyword: Visceral adipose tissue, cut off, DM, body mass index, waist circumference, abdominal CT scan

ABSTRAK

***Latar belakang**. Obesitas merupakan keadaan IMT ≥ 25 kg/m2. Visceral adipose tissue (VAT) yang terdeposit pada kondisi obesitas menjadi prediktor kejadian diabetes melitus tipe 2. CT scan merupakan pengukuran VAT yang akurat. Diperlukan nilai titik potong untuk mengetahui stratifikasi VAT yang berisiko terhadap DM tipe 2.*
***Metode**. Penelitian potong melintang pada pasien yang dilakukan pemeriksaan CT scan daerah abdomen di Instalasi Radiologi RSUP H. Adam Malik Medan selama Februari 2024. Sebagian data diambil dari penelitian Magister Kedokteran Klinik tahun 2022. Data yang diambil berupa IMT, lingkar pinggang, skor risiko DM, dan volume VAT pada pasien yang diperiksa dengan CT scan abdomen setinggi*

L4. Skor risiko DM diperoleh dengan kuesioner ADA diabetes risk score. Pengukuran volume VAT menggunakan 3D segmentation.

***Hasil**. Dari 116 pasien yang diteliti, jumlah sampel laki-laki sebanyak 53,4% dan perempuan 46,6%. Proporsi skor risiko tinggi DM 59,5%. Skor risiko DM yang tersering adalah 5. Dilakukan juga penilaian korelasi Spearman's. Nilai titik potong pada sensitivitas 44,93% dan spesifisitas 80,85% adalah 1.311,9 cm3. Keakuratan CT scan sebagai prediktor DM tipe 2 adalah baik (luas AUC 0,7). Nilai prediksi positif 77,50%, dan nilai prediksi negatif 50%. Nilai likelihood ratio positif 2,34 dan nilai likelihood ratio negatif 0,68.*
***Kesimpulan.** Pengukuran VAT dengan menggunakan CT scan abdomen sebagai prediktor DM tipe 2 memiliki akurasi baik.*

***Kata Kunci**: Visceral adipose tissue, cut off, diabetes melitus, indeks massa tubuh, lingkar pinggang, CT scan abdomen*

1. Introduction

Obesity, where the body mass index value is ⩾ 25 kg/m2, is a strong predictor of a person's risk of developing type 2 DM (type 2 DM) [1]. Based on the National indicators of 2015-2019 15.4% of the population aged over 18 years is obese [2]. This is in line with the increasing prevalence of central obesity (waist circumference ⩾ 90 cm in men and ⩾ 80 in women) increased from 26.6% to 31% [1-22]. VAT is considered to have a fairly strong relationship with metabolic risk. [4-9] VAT can release proteins that play a role in inflammation, atherosclerosis, dyslipidemia, and hypertension. Thus, VAT is more closely associated with type 2 diabetes than other obesity indices. Therefore, quantitatively accurate measurements of VAT are very necessary for evaluating the potential risk of metabolic, cardiovascular disease, infection, or malignancy. CT scans can measure VAT alone without any other fat in the body [1,23-29]. Intraabdominal fat can build up in Asians without a noticeable rise in total body mass. Cardiometabolic illnesses were shown to be prevalent among rural Filipino subjects at lower BMI cut-offs of 24 kg/m2 for males and 23 kg/m2 for females. While computed tomography (CT) and magnetic resonance imaging (MRI) are currently the gold standards for the quantification of visceral adiposity, they are considered too expensive, cumbersome, and/or invasive for routine clinical use. Waist circumference (WC) is a reliable surrogate marker of visceral fat mass, and its measurement is recommended in evaluating patients for obesity-related disease risk. Large population studies have shown a strong association between WC and the risk of coronary heart disease and type 2 DM, even in the absence of other risk factors such as hypertension, increased blood glucose, and dyslipidemia. Male and female health outcomes, as well as those of several ethnic groups and age groups, are consistently correlated with WC. Different WC measuring sites, such as above the iliac crest, midway between the lowest rib and iliac crest (as advised by the World Health Organisation), the narrowest part of the waist, or below the lowest rib, have been employed in various clinical investigations on cardiovascular morbidity and mortality. It is frequently recommended to employ bony anatomic features as instantly identifiable fixed measurement parameters. Numerous cross-sectional studies have tried to identify which WC measuring site most accurately represents visceral adiposity and cardiometabolic outcomes in the various ethnic groups, although there is no standard procedure for WC measurement. They concluded that the superior indicator of VFA and cardiometabolic risk was WC measured below the lowest rib. Similar results were seen in another study conducted in Ireland, where WC assessed below the lowest rib showed the highest correlations with DM, dyslipidemia, and hypertension in both sexes [8]. Undetected DM will increase the risk of complications quite high. Early detection of people at high risk of DM using a simple, non-invasive, and low-cost examination using the ADA diabetes risk score [24,30-35]. This study aimed to determine the cut-off VAT volume at risk of developing type 2 DM which is assessed using an abdominal CT scan. From the cut-off value obtained, we can determine the quantity of the VAT and whether a person's VAT is at high- or low risk of developing type 2 DM [36-39].

2. Methods

The study type is analytic and the design is cross-sectional. The process was carried out for 3 (three) months, during the period December 2023 to February 2024. Some of the data was taken during February 2024 and some more data was taken from the Master of Clinical Medicine study in 2022. Data was obtained from 116 samples, by collecting worksheets with ADA diabetes risk scores and measuring the sample's weight, height, and abdominal circumference. Inclusion criteria are patients aged 18-72 years who are registered in the medical record, and BMI more than or equal to 25. Samples with BMI 25-29,9 kg/m2 are categorized into grade I and others with BMI ⩾ 30 kg/m2 are categorized as obese grade II. Then samples underwent the CT scans of the abdomen at the Radiology Installation General Hospital H. Adam Malik Medan. Samples that met the exclusion criteria at the stage of filling in the worksheet or after an abdominal CT scan were excluded. VAT was measured using volumetric software (smartsegmentation) from Philips Ingenuity 128 slices with 5 mm thickness. Segmentation was taken from the superior until the inferior endplate of lumbar-4 vertebrae. Samples with VAT values ⩽ 1,311.9 cm3 were classified as having VAT with a low risk of developing type 2 DM, while those with VAT > 1,311.9 cm3 were classified as having VAT with a high risk of developing type 2 DM. The interclass correlation coefficient (ICC) is 0,75. The DM risk score was assessed with the ADA diabetes risk score. This questionnaire contains 7 questions regarding age, gender, history of diabetes in pregnancy, family history of hypertension, activity, weight, and height (BMI) based on race. DM is categorized as high risk if the ADA diabetes risk score value is greater than or equal to five. Data processing was carried out with SPSS software involving the cut-off value, sensitivity, specificity, negative predictive value, positive predictive value, likelihood ratio positive and negative, and also the correlation between VAT, waist circumference, and diabetes risk score. The study was conducted after obtaining approval for ethical clearance from the Research Committee for Health Sector, Faculty of Medicine, Universitas Sumatra Utara, and a license from General Hospital H. Adam Malik Medan. All patients who were willing to participate in this study were provided with informed consent in written form, either signed by him/herself or signed by their family members. In giving such consent, the patient has been informed of the meaning, benefits, and possible unpleasant side effects that may occur during the study.

3. Results

Table 1 shows from 116 samples, there were 62 men (53.4%), and female 54 (46.6%), obesity Grade I 82 (70.7%), and obesity Grade II 34 (29.3%). The average age of the subjects was 50,54±11,08 years old. The average body mass index (BMI) is 29,17 ± 3,47 kg/m2., the average VAT was 1.264,04 ± 844,74 cm3.

Table 1 Demographic Characteristics of Subjects

Characteristics	Result (mean±SD)
Age (years)	50.54±11.08
Body weight (kg)	75.95± 13.39
Body height (cm)	159.80±13.20
Waist circumference (cm)	97.29±8.23
BMI (kg/m^2)	29.17±3.47
VAT (cm^3)	1195.88±467.25
DM Risk score classification	
High Risk	69(59.5%)
Low Risk	47(40.5%)

Based on Table 2, of the 116 obese samples, 82 people (70.7%) were classified as grade I obese, and Low Risk DM 65%.

Table 2 Sample Distribution Based on Degree of Obesity

Parameters	Frequency (n)	Percentage (%)
Grading of obesity		
I (25-29,9 kg/m^2)	82	70.7
II (≥30 kg/m^2)	34	29.2
VAT Category		
Low Risk DM (≤ 1311.9 cm^3)	76	65.5
High Risk DM (> 1311.9 cm^3)	40	34.5

Based on Table 3, all samples were assessed using the ADA diabetes risk score to determine the risk of type 2 DM.

Table 3 Sample Characteristics Based on Type 2 DM Risk Score

Characteristics	Result	Frequency (n)	Percentage (%)
Minimum Score	2	8	6.9
Maximum Score	9	4	3.4
Most often score	5	28	24.1
Low Risk DM	≤ 4	47	40.4
High Risk DM	≥ 5	69	59.5

Based on Table 4, the distribution of waist circumference in the sample was divided based on gender. Male, WC with DM risk (≥90 cm) 49.3% and female, WC with DM risk (≥ 80 cm) 46.55%.

Table 4 Distribution of Waist Circumference

Sex		Frequency (n)	Percentage (%)
Male	WC with DM Risk (≥90 cm)	57	49.13
	WC without DM Risk (<90 cm)	5	4.31
Female	WC with DM Risk (≥ 80 cm)	54	46.55
	WC without DM Risk (< 80 cm)	0	0
Total		116	100

Note: WC= Waist Circumference

Based on Figure 1, the distribution of sample VAT is based on the sample waist circumference of all females with high-risk DM.

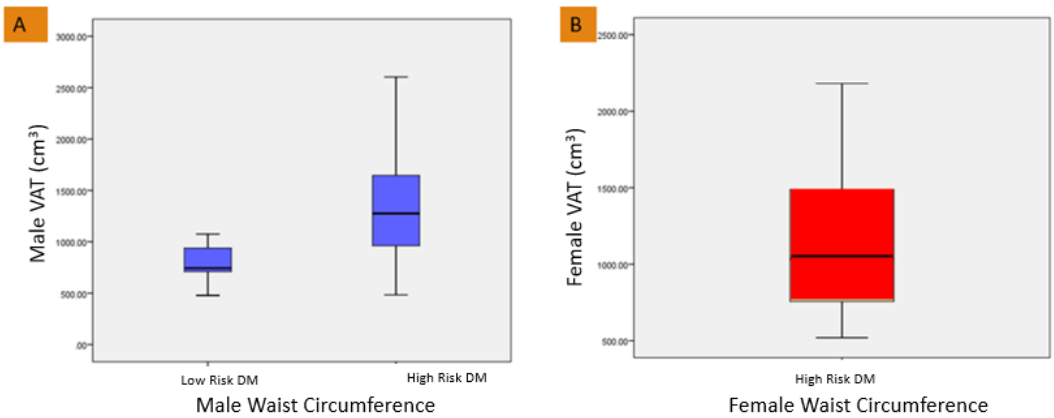

Figure 1 Distribution of sample VAT based on sample waist circumference.

Based on Table 5, there is a correlation significantly between all obesity parameters and VAT.

Table 5. Correlation between VAT and obesity parameters

Obesity Parameter	r	p
WC	0.616	< 0.01
DM-score	0.346	< 0.01
IMT	0.000	< 0.01

Based on Figure 2, the patient had a BMI of 32 kg/m^2, a DM risk score of 7, a waist circumference of 100 cm, and a VAT volume of 1,658.2 cm3. VAT volume was calculated automatically after doing the segmentation (red ellipse circle).

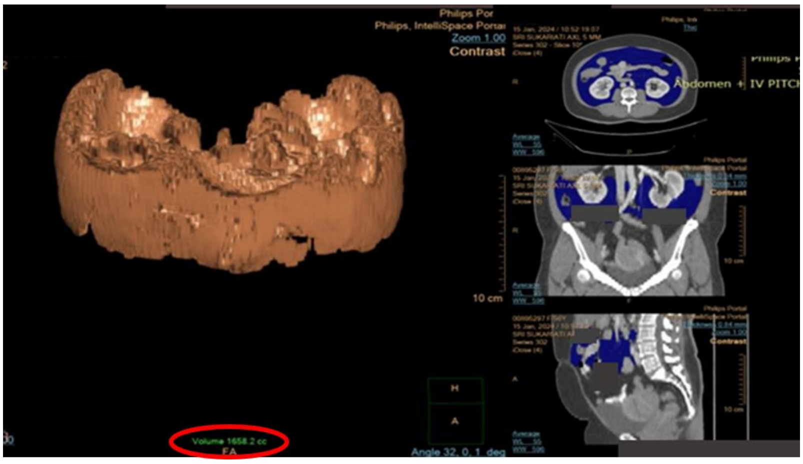

Figure 2 VAT volume segmentation and measurement results. VAT volume is presented in 3D form (the brown picture) representing the volume of visceral adipose tissue, generated from CT Philips 128 Ingenuity. Blue segmentation of orthogonal plain (axial, coronal, and sagittal) in 2D CT shows the level of VAT is at L4 The cut point value of VAT volume is 1.311,9 cm^3 (figure 3) and has a sensitivity of 44,9% specificity of 80,9%, PPV of 77.50%, and NPV of 50% (Table 6,7).

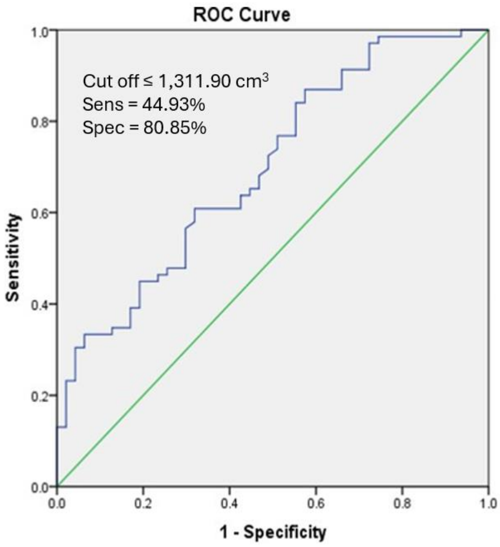

Figure 3. The Receiver Operating Characteristic (ROC) Curve.

Table 6 Cut-off, Sensitivity, and Specificity Test

Cut-off value of VAT (cm^3)	Sensitivity (%)	Specificity (%)
477,7000	1,000	0,000
1121,6500	0,609	0,681
1311,9000	**0,449**	**0,809**
1650,7000	0,275	0,957
2605,0000	0,000	1,000

Table 7 Accuracy of VAT cut-off value in Predicting DM Type 2 Risk

VAT	**Degree of DM Risk**		**Sensitivity**	**Specificity**	**PPV**	**NPV**
	High	Low				
>1.311,9 cm^3	31	9	44.93%	80.85%	77.50%,	50%
≤1.311,9 cm^3	38	38				

4. Discussions

The sample distribution based on individual characteristics shown in Table 1 shows that the average age of this research sample is 50.54 ± 11.08 years, with a total sample of 116 people. In research conducted by Oh et al in Korea, the average age of the study sample was 52.1 ± 9.9 years for men and 50.6± 9.7 years so it is not much different from the average age in this research sample [22]. Research conducted by Pescatory et al used a sample aged 57 ± 15 years from 31 people, to see the accuracy of MRI and CT scans in calculating VAT volume [6]. The age range included in the inclusion criteria in this study was 18 to 72 years. Research conducted by Pescatory et al found that the age range of the research sample carried out was also quite wide, namely 34-92 years old [6]. Based on the ADA Diabetes Risk Score table, the older the patient, the higher the score obtained. [34] Kaess conducted the study and looked at the comparison of VAT and the VAT/SAT ratio to see cardiometabolic risk using abdominal CT scans. The average age in Kaess's study was 51.8 ± 9.7 years in women and 49.5 ± 10.6 years in men. Kaess also used some data from his research which was described previously [14]. Obesity, where the body mass index value is ⩾ 25 kg/m2, is a strong predictor of the risk of developing type 2 DM (type 2 DM) [1]. In Indonesia, 13,5% of adults aged 18 years and over are overweight, while 28,7% are obese [2] From Figure 1 it can be seen that the largest number of research samples was in the 40-49 year age group, even though the average patient age was 50.54 ± 11.08 years. This means that as a reference for age to be a predictor of type 2 DM, numbers from the age group are still productive men. This study uses BMI as a determinant of inclusion criteria. According to Nasution et al, in 2023, it was found that there was a correlation between BMI and VAT (r=0.687; $p < 0.001$) [26]. It is known that BMI ⩾ 25 kg/m2 for Asian people is categorized as obesity. In this study, researchers wanted to see what kind of obesity can cause a person to suffer from type 2 DM. It is said that BMI is not specific for looking at a person's obesity condition. So a more detailed examination is carried out and the fat volume is directly measured. The measured fat is presented as VAT and SAT. According to much literature, VAT is more dangerous than SAT, because VAT can easily move into the blood circulation [12,31]. In this study, all patients with a BMI ⩾ 25 kg/m2 and who met the inclusion criteria had their VAT measured using an abdominal CT scan. The BMI values obtained in this study were 28.89 ± 2.89 kg/m2 in men and 29.50 ± 4.03 kg/m2 in women. In a study by da Rosa et al in 2021, it was found that the average BMI value in patients who were not at risk of metabolic syndrome was 25.7 ± 3.6 kg/m2, and in those who were at risk of metabolic syndrome was 29.8 ± 6.2 m2. For this categorization, Da Rosa uses blood sugar checks on his samples first [17]. The average VAT obtained was 1,195.88 ± 467.25 cm3 in all samples. Da Rosa et al.'s research on military men in Korea found that the average VAT in samples without a risk of metabolic syndrome was 806.4 ± 597.6 cm3 and in those with a risk of metabolic syndrome it was 1550.6 ± 716.8 cm3. The average VAT value obtained in our study is almost similar to the research value from da Rosa. According to the cut-off point value in our study, the average VAT in samples at low risk of type 2 DM was 916.56 ± 27.36 cm3 and the average VAT in samples at high risk of type 2 DM was 1,726 .58 ± 48.32 cm3. The average value obtained by the author is higher than that obtained by da Rosa et al. One of the influencing factors is that da Rosa researched a sample of military men who were accustomed to physical activity/exercise [17]. From the average VAT volume based on gender, the VAT value was found to be 1,395.56 ± 1,070.51 cm3 in male samples and 1,113.03 ± 431.18 cm3 in female samples. Kaess, with his research in Europe, found that the average VAT for men was 2,226 ± 1,020 cm3 and for women 1,350 ± 829 cm3. The patient's age and BMI are almost the same [34]. The average BMI of the Kaess sample is 28.4 ± 4.5 kg/m2 in men and 27.0 ± 5.8 kg/m2 in women [34]. The difference in the average VAT results obtained is likely due to racial differences.

From the distribution of fat volume based on gender, the distribution of fat storage in women is predominantly in the inferior area of the body, while in men it tends to be superior. Differences in hormone levels also play a role in this (the physiological action of estrogen versus testosterone). Women's fat distribution is different from men's because it is mainly to facilitate reproduction and provide sufficient nutritional intake for the fetus [9,14]. In line with the theory above, from this study, we found that the average VAT in men is higher than in women. Based on the examination in this research, the average waist circumference was 97.29 ± 8.23 cm. If we look by gender, the average waist circumference for men is 97.72 ± 7.31 cm, and for women is 96.79± 9.21 cm. The minimum waist circumference is 80 cm and the maximum is 122 cm. If we look at Kaess's research, the average waist circumference of the male sample was 100.8 ± 11.8 cm and that of women was 93.0 ± 15.4 cm. The waist circumference of the male sample in Kaess's study was larger, while the waist circumference of the male sample of the women was smaller than the ones we got. This can be explained according to the theory presented by Perjasamy that biologically, Asian people are more likely to store fat in the abdominal area. In more depth, it is said that the dietary factor in Asians is rice consumption, which is an average of 4 times more than Europeans in a day, giving rise to more fat deposition in the abdominal area which of course will increase waist circumference [9]. DM risk was measured using the ADA diabetes risk score questionnaire. Previously, research had been conducted in Indonesia using the PERKENI questionnaire, the contents of which were also adopted from the ADA diabetes risk score. Kamal RH et al researched the risk of diabetes in the population in Bangkalan in 2015, and those at high risk underwent an oral glucose tolerance test (OGTT) [36]. Although this questionnaire was designed by the ADA, Haribuwono, et al in 2021 have researched its use in Indonesia. The results are no different from the country of origin because the questionnaire has been designed in such a way based on race, gender, activity, history of type 2 DM, and hypertension. The cut point determined is also the same, namely ⩽4. This means that Indonesian people with a risk score ⩽ 4 have a low risk of type 2 DM [27]. According to the consensus of the International Atherosclerosis Society (IAS) and the International Chair on Cardiometabolic Risk (ICCR) Working Group on Visceral Obesity, waist circumference is an examination that is essential for clinicians to stratify diseases related to obesity [5]. In a clinician setting, waist circumference represents di visceral fat [8]. Waist circumference above or equal to 80 cm for women and 90 cm for men is classified as visceral obesity [5]. In this study, a moderate positive correlation (r=0.613, p< 0,01) was found between body mass index and waist circumference. Based on calculations, the waist circumference value is moderately correlated with VAT volume (r=0,616, p< 0,01) but weakly correlated with DM risk score (r=0,277, p< 0,01). According to da Rosa, the correlation between the VAT of samples without a risk of metabolic syndrome and those with waist circumference is 0,885, and the VAT of samples with a risk of metabolic syndrome and waist circumference is 0,836. So et al in Japan (2017) obtained a correlation value for waist circumference with VAT that was almost the same as in this study, namely 0.62 [29]. In this study, the correlation between VAT and DM risk score was weak, namely r = 0.346. Until this research was conducted, there were no references that mentioned the correlation between VAT and DM risk scores or waist circumference and DM risk scores. However, Fox, 2007 found a correlation between VAT and fasting glucose levels, namely r=0.34 in women and r=0.19 in men. [15] This weak correlation between DM scores and VAT could be possible due to various other factors. Such as a history of hypertension, food intake, and activities that were not controlled in this study [39]. The increasing incidence of obesity due to modernity, various convenience services, a relaxed lifestyle, and a high-calorie diet, will ultimately increase the accumulation of body fat [31]. This increasing incidence of obesity is certainly an increasingly worrying metabolic disease [2]. It is known that the risk of type 2 DM is increased in patients with central obesity. Using BMI as a benchmark for obesity stratification alone is not sufficient, because it is not specific to VAT. VAT measurements with various modalities have been demonstrated by various experts. Among the many radiological modalities, DXA, MRI, and CT scan are the gold standards for measuring VAT volume. However, due to its affordability, CT scans are the main choice [32]. There have been many studies using measurements VAT with CT scans including Fox, 2007 in the Framingham study to look at cardiometabolic events, Yoo et al in 2020 in Arabia, and da Rosa et al in Korea in 2021 [15-17]. Bunnel, 2021, in the United States stratified patients at high risk of COVID complications, which were associated with visceral fat levels which were measured using an abdominal CT scan at lumbar level 4 (L4) [23,34]. This research has almost the same principle as that carried out by Bunnel and friends, namely using two CT scan tools (GE Brighspeed and Philips Ingenuity 128), then volumetric measurements are made on one tool in the form of a 3D clip and smart segmentation on the Philips Ingenuity 128 workstation. Using measurement principles such as the protocol mentioned by Shuster and friends, then the entire slice thickness is adjusted again with the slab to a thickness of 5 mm [32]. The anthropometry used in this study was BMI and waist circumference. It is also known that there are several measurements in assessing anthropometry, namely, arm circumference, skin fold, and waist-hip ratio. Previous researchers stated that BMI is the most frequently used anthropometric technique [32]. Apart from BMI, waist circumference remains the choice of clinicians for stratifying obesity. According to the Pedoman Pengelolaan dan Pencegahan DM Type 2 di Indonesia 2019, it is stated that central obesity occurs if the waist circumference is ⩾ 90 cm in men and ⩾ 80 cm in women. This is to the statement from the IAS and ICCR that waist circumference is used to see the stratification of obesity, especially metabolic syndrome disease. Therefore, CT scans to see total fat in the body here are compared with waist circumference measurements [5,8]. Before calculating inferential statistics in this research, an examination of the similarity of measurement results between readers (Interclass correlation for interreader comparison) was first carried out. From calculating the Kappa value, the result was 75%, which means good, which means that the inferential statistical analysis can be continued. If the Kappa value is <60%, then the research analysis cannot continue. Based on this test, the inferential analysis is continued using one of the data sets. This Kappa value shows that differences between readers in measurements (in this case researchers and radiologists) are minimal. As we know, variations in research results can be caused by measurement factors and biological factors. Variation is the square of the standard deviation. The standard deviation value is a value that shows the level (degree) of variation in a group of data or a standard measure of deviation from the mean [35].

In this study, the research variations were quite large, which can be indicated by the fairly large standard deviation values. The main possibility of this variation comes from biological aspects. Biological variation can arise from within an individual (changes in a person over time and situations) or from several individuals (biological differences from person to person). Biological variation between individuals is the most likely to occur in this study. In this study, the inclusion criteria included age and BMI [35]. In addition, in the ADA Diabetes risk score questionnaire which is used as a tool in determining the risk of type 2 DM, there are other factors besides BMI and history of diabetes, such as activity, hypertension, and history of previous pregnancy.

All of which were not controlled for in this study. Based on the normality test, the VAT data from this study has a non-normal distribution. Therefore, in the ROC, the curve forms a jagged/staircase picture [37]. Harbuwono et al. have researched the possibility of the ADA questionnaire replacing the random KGD examination in diagnosing undetected DM or prediabetes. The results obtained were that at a score of ⩾5 the sensitivity was 68%, while at a cut point of score ⩾4, the sensitivity increased to 93%. The ADA diabetes risk score questionnaire has good accuracy, namely AUC 0.71. This questionnaire gives good results when the cut-point value taken is ⩾ 5 [27]. The ADA questionnaire is a questionnaire formed by closed questions, so there is no need for construct validation for the application. Content validation can be carried out by including the researcher's contact number so that subjects who do not understand can contact them directly. Researchers also try to be present to accompany patients when filling out questionnaires.

All patients were examined using a CT scan covering the abdominal area at L4 level and a statement was made stating their willingness to take part in research activities. Of course, to reduce biological variation, a larger sample size and stricter inclusion criteria are needed [35]. Although the variations and standard deviations of the results of this study are quite large, the results of other studies such as those obtained by So and his friends also have standard deviations that are also quite large [29]. This research data processing uses SPSS software. The cut point value is calculated based on the ROC curve. The cut point was adjusted to find the best balance between sensitivity and specificity. From the calculations in Table 3 above, the cut-off point value is obtained, where a VAT value ⩽ 1,311.9 cm3 is considered to be at low risk of type 2 DM, while VAT > 1,311.9 cm3 is considered to be at risk of type 2 DM. Da Rosa's study in Korea using DXA found the intercept number 1.025 cm3. The cut point value for da Rosa's study is slightly smaller than the results of our research, possibly because the subjects of da Rosa's research were soldiers who were used to doing physical activity. For a diagnostic method in the form of a cut point to be accepted, the AUC value must be above 0.5 with a 95% confidence interval. In this study, an AUC value of 0.7 was obtained, which means good [38]. The curve line is above the diagonal line and does not intersect, indicating that this examination method is acceptable. Other literature states that an AUC of 0.7 is satisfactory [37]. Yoo et al 2019 determined the cut-off value for identifying metabolic complications in residents of the United Arab Emirates, with the AUC results for male VAT being 0.706 and female 0.742. The results obtained by Yoo were slightly greater than those we obtained in this study, possibly because in Yoo's study the sample size was larger, namely 369 people, the stratification of research subjects was more detailed, and the determination of the state of metabolic syndrome was also based on laboratory examinations such as OGTT and lipid profile [16]. Based on these values, the sensitivity value can be measured, namely 44,93%, specificity 80,85%, positive predictive value (PPV) 77,50%, and negative prediction (NPV) 50%. The more sensitive a tool is, the less specific it is. In this study, the specificity of the tool was 80,85%, which means that VAT examination with an abdominal CT scan was able to show which individuals were not at risk of type 2 DM from those whose VAT was ⩽ 1,311.9 cm3. As a predictor, the specificity value is expected to be above 80%. In this study, the value was 80,85%. The positive predictive value of this examination is 77,50%, which means that if a person's VAT value is > 1,311.9 cm3, the probability that the subject is at risk of type 2 DM is 77,50%. The positive likelihood ratio (LR +) is 2,34 and the negative likelihood ratio (LR -) is 0,68. LR (+) 2,34 means that 2,34 times the chance of someone being at risk of type 2 DM is greater in people whose VAT is more than 1,311.9 cm3. This LR (+) value is classified as satisfactory. An LR (-) value of 0,68 means that a person is likely not at risk of type 2 DM at VAT ⩽ 1,311.9 cm3. This LR (－) value is classified as satisfactory [37]. Due to consecutive sampling, in this study, there were more samples with VAT volumes that were less at risk of type 2 DM (⩽1,311.90 cm3) than those at risk. Of course, this can have an impact on the risk of DM becoming less risky. It is difficult for researchers to obtain obese samples with a BMI of more than 30, as is the case in the literature. The number of samples with a BMI > 30 was only 34 people. This is possibly because this research was conducted in a tertiary health care center with a tendency for patients to come with various chronic diseases that have disrupted intake and metabolism processes. It is not uncommon for researchers to get samples with BMI grade 2 obesity but who already suffer from type 2 DM or malignancies so they must be excluded.

Even though the ADA criteria are very good in screening for type 2 DM, the factors in them are very significant in providing meaning. Because this research uses the method of filling out a questionnaire by the sample/family, of course, there is a factor of honesty and knowledge about the research object when filling it out. It is hoped that the filling will be honest and precise to avoid bias.

5. Conclusions

Based on this study, VAT levels are a predictor of risk for type 2 DM with good accuracy (AUC 0.7) with specificity of 80,85% and positive predictive value of 77,5%. The cut-off value of VAT volume as a predictor of type 2 DM risk is > 1,311 cm^3.

Acknowledgements

The author would like to express gratitude to all patients, lecturers, and laboratory staff, who have helped in carrying out this research.

Conflict of Interest

The authors declare no conflict of interest in this research.

References

[1] *Kementerian Kesehatan Republik Indonesia. Dirjen P2PTM. Factsheet Obesitas*. 2018. *Available from* http://p2ptm.kemkes.go.id/dokumen-ptm/factsheet-obesitas-kit-informasi-obesitas

[2] *Kementerian Kesehatan Republik Indonesia. Rencana Strategis Kementerian Kesehatan Tahun 2015-2019. Jakarta: Kementerian Kesehatan Republik Indonesia.*

[3] *Perkeni. Pedoman Pengelolaan Dan Pencegahan Diabetes Melitus Tipe 2 Dewasa Di Indonesia. PB Perkeni. 2021.*

[4] Pangribowo S, Boga H, Widiantini W, Muliya D, dan Ma'ruf A. *Infodatin*.Kementerian Kesehatan Republik Indonesia. Dirjen P2PTM. 2020.

[5] Ross R, et al. Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. *Nat Rev Endocrinol*. 2020 Mar;16(3):177-189.

[6] Pescatori LC, et al. Quantification of visceral adipose tissue by computed tomography and magnetic resonance imaging: reproducibility and accuracy. *Radiol Bras*. 2019 Jan-Feb;52(1):1-6.

[7] Kementerian Kesehatan RI. Pedoman Teknis Penemuan dan Tatalaksana Hipertensi di Indonesia. Jakarta: Kementerian Kesehatan RI. 2016.

[8] Kawaji LD, Fontanilla JA. Accuracy of Waist Circumference Measurement Using the WHO versus NIH Protocol in Predicting Visceral Adiposity Using Bioelectrical Impedance Analysis among Overweight and Obese Adult Filipinos in a Tertiary

[9] Leslie Daphne Kawaji, Joy Arabelle Fontanilla. Accuracy of Waist Circumference Measurement using the WHO versus NIH Protocol in Predicting Visceral Adiposity Using Bioelectrical Impedance Analysis among Overweight and Obese Adult Filipinos in a Tertiary Hospital Journal of the ASEAN Federation of Endocrine Societies: November 202:36;2:180-188.

[10] Williams R, Perjasamy M. Genetic and Environmental Factors Contributing to Visceral Adiposity in Asian Populations. Endocrinol Metab (Seoul). 2020; 35(4): 681–695. Published online 2020 Dec. 31. doi: 10.3803/EnM.2020.772.

[11] Bunnel et al. Body composition predictors of outcome in patients with COVID-Clinical Research. *International Journal of Obesity*. 2021. DOI 10.1038/s41366-021-00907-1

[12] Tchernof A, Després JP. Pathophysiology of human visceral obesity: an update. *Physiol Rev*. 2013 Jan;93(1):359-404. doi: 10.1152/physrev.00033.2011. PMID: 23302913.

[13] Shuster A, Patlas M, Pinthus JH, Mourtzakis M. The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. *The British Journal of Radiology*. 2021. 85, 1-10.

[14] Mittal B. Subcutaneous adipose tissue and visceral tissue. *Indian J Med Res*. 149: 571-3. 2019. DOI 10.4103/ijmr.IJMR_1910_18

[15] Storz C et al. The Role of Imaging in Obesity Special Feature: Full Paper. The role of visceral and subcutaneous fat tissue measurements and their ratio by magnetic resonance imaging in subjects with prediabetes, diabetes, and healthy controls from a general population without cardiovascular disease. *Br J Radiol*; 2018. 91:20170808

[16] Yeoh AJ, Pedley A, Rosenquist KJ, Hoffmann U, Fox CS. The Association Between Subcutaneous Fat Density and the Propensity to Store Fat Viscerally. *J Clin Endocrinol Metab*. 2015 Aug;100(8):E1056-64.

[17] Triggiani AI et al. Heart rate variability reduction is related to a high amount of visceral adiposity in healthy young women. *PLOS one*. 2019. DOI.org/10.1371/journal.pone.0223058.

[18] Kwon H, Kim D, Kim JS. Body Fat Distribution and the Risk of Incident Metabolic Syndrome: A Longitudinal Cohort Study. *Sci Rep*. 2017;7(1):10955. Published 2017 Sep 8. doi:10.1038/s41598-017-09723-y

[19] Fox et al. Abdominal Visceral and Subcutaneous Adipose Tissue Compartments. Association with Metabolic Risk Factors in the Framingham Heart Study. *Circulation*. 2007. 116:39-48.

[20] Yoo S, Sung MW dan Kim H. CT-Defined visceral adipose tissue thresholds for identifying metabolic complications: A cross-sectional study in the United Arab Emirates. *BMJ*. 2020.031181

[21] Ezquerra EA, Vazquez MC, dan Barrero AA. Obesity, Metabolic Syndrome, and Diabetes: Cardiovascular Implications and Therapy. *Rev Esp Cardiol*. 2008. 61(7):752-64

[22] da Rosa SE, Amina Chain Costa, Marcos S R Fortes, Runer Augusto Marson , Eduardo Borba Neves, et al. Cut-Off Points of Visceral Adipose Tissue Associated with Metabolic Syndrome in Military Men. *Healthcare* (Basel). 2021 Jul 14;9(7):886. doi: 10.3390/healthcare9070886.

[23] Kaess BM, A Pedley, J M Massaro, J Murabito, U Hoffmann, C S Fox, et al. The ratio of visceral to subcutaneous fat, a metric of body fat distribution, is a unique correlate of cardiometabolic risk. *Diabetologia*. 2012. 55(10):2622

[24] Eastwood SV et al. Estimation of CT-Derived Abdominal Visceral and Subcutaneous Tissue Depots from Anthropometry in Europeans, South Asians and African Caribbeans. *PLOS ONE*. 2013. 8:1-12

[25] ACR-SABI-SAR practice parameter for the performance of computed tomography (CT) of the abdomen and computed tomography (CT) of the pelvis. ACR. 2021. Accessed May 20, 2024. Available from https://www.acr.org/-/media/ACR/Files/Practice-Parameters/ct-abd-pel.pdf

[26] Ryo M, Kishida K, Nakamura T, Yoshizumi T, Funahashi T, Shimomura I. Clinical significance of visceral adiposity assessed by computed tomography: A Japanese perspective. *World J Radiol*. 2014;6(7):409-416. doi:10.4329/wjr.v6.i7.409

[27] Weston AD, Panagiotis Korfiatis, Timothy L Kline, Kenneth A Philbrick, Petro Kostandy, et al. Automated Abdominal Segmentation of CT Scans for Body Composition Analysis Using Deep Learning. *Radiology*. 2019;290(3):669-679. doi:10.1148/radiol.2018181432

[28] Kim SS, Kim Jae-Hun; Jeong Woo Kyoung, Lee Jisun, Kim, Young, et al. Semiautomatic software for measurement of abdominal muscle and adipose areas using computed tomography: A STROBE-compliant article. *Medicine (Baltimore)*. 2019;98(22):e15867. doi:10.1097/MD.0000000000015867

[29] Philips. *Manual Book Philips Ingenuity 128*. Philips; 2020.

[30] Oh YH, Moon JH, Kim HJ, Kong MH. Visceral-to-subcutaneous fat ratio as a predictor of the multiple metabolic risk factors for subjects with normal waist circumference in Korea. *Diabetes Metab Syndr Obes*. 2017;10:505-511. Published 2017 Dec 11. doi:10.2147/DMSO.S150914

[31] Nasution DRS, Lubis ND, Dalimunthe NN. The Correlation of Body Mass Index with Visceral and Subcutaneous Adipose Tissue Volume in Patients that Performed Abdominal CT Scan at RSUP H. Adam Malik Medan. Bulletin Farmatera. 2023. Available at https://jurnal.umsu.ac.id/index.php/buletin_farmatera/article/view/12656/8471

[32] Harbuwono DS, Mokoagow MI, Magfira N, Helda H. ADA Diabetes Risk Test Adaptation in Indonesian Adult Populations: Can It Replace Random Blood Glucose Screening Test? *J Prim Care Community Health*. 2021;12:21501327211021015. doi:10.1177/21501327211021015

[33] Mohd Fauzi NF, Wafa SW, Mohd Ibrahim A, Bhaskar Raj N, Nurulhuda MH. Translation and Validation of American Diabetes Association Diabetes Risk Test: The Malay Version. *Malays J Med Sci*. 2022 Feb;29(1):113-125. doi: 10.21315/mjms2022.2950,54±11,08.1.11.

[34] So R, Matsuo T, Saotome K, Tanaka K. Equation to estimate visceral adipose tissue volume based on anthropometry for workplace health checkup in Japanese abdominally obese men. *Ind Health*. 2017;55(5):416-422. doi:10.2486/indhealth.2017-0060

[35] American Diabetes Association Professional Practice Committee; 2. Classification and Diagnosis of Diabetes: *Standards of Medical Care in Diabetes—2022*. *Diabetes Care* 1 January 2022; 45 (Supplement_1): S17–S38. https://doi.org/10.2337/dc22-S002

[36] Kamal RH Faizah Chadijah, Galan Budi Prasetya, Gilang Satria Pratama, Mentari Octarina, et al. Diabetes risk factor screening in adults using Perkeni questionnaire and oral glucose tolerance test in Socah County, Bangkalan. *Folia Medica Indonesiana*, 2017. *53*(3), 199–203. https://doi.org/10.20473/fmi.v53i3.6448

[37] Riyanto A. *Pengolahan dan Analisis Data Kesehatan Dilengkapi Uji Validitas dan Realibilitas serta Aplikasi Program SPSS*. Numed. 2009.

[38] Nahm FS. Receiver operating characteristic curve: overview and practical use for clinicians. *Korean J Anesthesiol*. 2022;75(1):25-36. doi:10.4097/kja.21209

[39] Area Under the Curve (AUC): Robust Performance Measure of Classification Models. medium.com. Published on August 04, 2023. https://medium.com/@bayramorkunor/area-under-the-curve-auc-a-robust-performance-measure-of-classification-models-cbfc3549d8c6

[40] Schober P, Boer C, Schwarte LA. Correlation Coefficients: Appropriate Use and Interpretation. *Anesth Analg*. 2018;126(5):1763-1768. doi:10.1213/ANE.0000000000002864.