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COMPARISON OF VISCERAL FAT THICKNESS MEASURED USING ULTRASONOGRAPHY IN PATIENTS WITH METABOLIC SYNDROME AND NORMAL SUBJECTS

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ABSTRACT

BACKGROUND: Metabolic syndrome is a cluster of metabolic abnormalities associated with an increased cardiovascular risk. Visceral fat thickness (VFT) has been proposed as a potential predictor of metabolic syndrome owing to its correlation with central obesity and insulin resistance **AIM:** This study aimed to correlate the sonographic measurement of visceral fat thickness (VFT) in patients with existing metabolic syndrome. **METHODS:** This cross-sectional study conducted over 18 months included 300 participants categorized into Metabolic syndrome (n=150) and normal control (n=150) groups from the Radiology department at SRM Medical College and Research Centre, Chengalpattu. VFT was measured using grey scale ultrasound and participants were stratified into two groups based on the VFT measurement. Statistical analyses, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and correlation coefficients were performed. Additional data on patients age, gender, mean weight, mean height, mean Basal metabolic index, HbA1c, Waist circumference, Hypertension, Diabetes mellitus, Total cholesterol levels, Triglyceride levels, Mean High-Density Lipoprotein (HDL) levels, Mean Very Low- Density Lipoprotein (VLDL) levels, Mean Low-Density Lipoprotein (LDL) levels was taken. **RESULTS:** Significant differences were found between the metabolic syndrome and control groups in terms of BMI, waist circumference, HbA1c, triglyceride, HDL cholesterol, Hypertension, Diabetes mellitus, and VFT (all $p < 0.0001$). Using a VFT cut-off of 6.45 cm, the sensitivity was 71.33%, specificity 84.00%, PPV 81.68%, NPV 74.56%, and accuracy 77. 67%. Correlation analysis showed strong positive correlations between the VFT and BMI (r=0. 882), waist circumference (r = 0 . 323), HbA1c (r=0. 893), and triglycerides (r=0. 774) ($p<0.0001$ for all), but no significant correlation with total cholesterol (r=0.082, p=0.158).**CONCLUSION:** The VFT demonstrated good diagnostic performance and significant correlation with key metabolic parameters, supporting its utility as a supplementary tool for predicting metabolic syndrome. These findings underscore the clinical relevance of VFT assessments for assessing metabolic risk.

INTRODUCTION

Obesity is a multifaceted and increasingly prevalent metabolic disorder that poses a significant threat to global public health, contributing substantially to millions of annual deaths worldwide.[1] In 2008 data showed >1.4 billion adults in the age group of more than 20 years, were reported as overweight, and over 200 million men population and 300 million women population were obese. In the Indian population, 1.3 % of male populations and 2.5% of female populations aged > 20 years were found to be obese.[2] Of particular concern is the accumulation of central fat, which serves as a pivotal risk factor for both metabolic and cardiovascular diseases, especially among individuals struggling with overweight and obesity.

Many studies have shown a strong association between high levels of abdominal fat and various health issues, such as high blood sugar, diabetes, high blood pressure, and metabolic syndrome.[3] Therefore, measuring abdominal fat accurately is crucial for any detailed research that aims to identify risk factors for metabolic diseases. While common methods like body mass index (BMI), abdominal circumference (AC), and waist circumference (WC) are often used, they usually do not effectively differentiate between subcutaneous

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and visceral fat, which limits their ability to predict the risk of metabolic and heart diseases.[4,5]

Imaging methods like CT scans and MRI scans can provide good estimates of abdominal visceral fat thickness, but their use in regular medical practice is limited due to issues like radiation exposure, high costs, and accessibility. On the other hand, ultrasound has become a strong alternative. It is a simple, accurate, non-invasive, affordable, and dependable way to estimate both intra-abdominal and visceral fat. Studies indicate that ultrasound is as accurate as CT scans for measuring visceral fat, making it a suitable choice for everyday clinical use.

Both subcutaneous and visceral fat are known to be linked to metabolic risks, but visceral fat shows a stronger connection to metabolic syndrome. New studies indicate that measuring abdominal fat thickness with ultrasound, especially in women, may relate more closely to metabolic risks than standard body measurements. [6-9]

Two hypotheses suggest a substantial link between visceral fat and Metabolic Syndrome, although the actual molecular pathways remain unknown. Visceral fat's closeness to the portal vein causes direct drainage of metabolites and free fatty acids into the liver, resulting in insulin resistance and enhanced gluconeogenesis. Another idea is that visceral adipocytes' enhanced lipolysis may cause detrimental visceral fat formation compared to subcutaneous abdominal deposition. As a result, this study aimed to investigate the association between VFT measurements on ultrasound and individuals with Metabolic Syndrome.

The goal of the present study was to correlate visceral fat thickness measured via ultrasonography in metabolic syndrome with normal subjects as the control group. Most of the previous studies have used CT scans for assessing visceral fat thickness in metabolic syndrome. However, CT scan has the disadvantage of radiation exposure and cost. USG is a readily available and cost-effective method to assess visceral fat thickness, so it is in this context, that the study was proposed.

AIMS AND OBJECTIVES

To correlate visceral fat thickness measured on ultrasonography in patients with metabolic syndrome and normal subjects.

MATERIALS AND METHODS

This was a cross-sectional study that was carried out in the Department of Radio Diagnosis, SRM Medical College Hospital and Research Centre, from December 2022 to June 2024. The study included 300 patients who were sent to the hospital's Department of Radiodiagnosis for USG abdominal imaging with diverse abdominal pathological indications.

The study was approved with Ethical clearance certificate number – SRMIEC-ST0722 -02 and informed consent was taken from all patients.

The participants were divided into two groups, each containing 150 patients between the age group of 21- 60 years. Group I (MS) contained patients fulfilling the metabolic syndrome criteria according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP -ATP III, 2005 revision).[10]

National Cholesterol Education Program Adult Treatment Panel III (NCEP -ATP III, 2005 revision) criteria for metabolic syndrome. Diagnosis requires at least three of the following five criteria.

- Abdominal obesity: waist circumference > 40 inches in men and >35 inches in women.
- Elevated triglyceride level (≥ 150 mg/d L)
- Reduced HDL cholesterol: <40 mg/dL in men and <50 mg/dL in women.
- Elevated blood pressure: ≥ 130/85 mmHg.
- Elevated fasting glucose level of ≥100 mg/dL

Group II (N) contains normal control patients without metabolic syndrome having Normal blood pressure, Normal lipid profile, Normal blood sugar levels, and Waist circumference <40 inches in men and <35 inches in women.

EXCLUSION CRITERIA - Pregnant females, Patients with endocrine abnormalities, including thyroid disorders with gross abdominal pathology, and Patients with chronic conditions such as cirrhosis, cancer, or renal failure were excluded from the study.

METHODOLOGY

Anthropometric measurements were taken such as (A)Weight, (B)Height. (C)BMI of all patients was calculated using the formula - weight (in kg) divided by the height in meter square (m^2). Waist circumference was measured at the junction between the lowermost rib being the upper limit and the iliac crest being the lower limit.

The patients were placed in supine position with arms extended above the head and were instructed about the examination and its time, and how to take and hold a deep breath which is required to avoid respiratory artifacts.

All scans were performed on a single Logiq P9 ultrasound system (GE, USA) with a 3.5 to 5 MHz multifrequency convex transducer by a single examiner. Ultrasound scans were performed with the patient in the dorsal decubitus position, measuring subcutaneous and VFT. A convex 3 .5 -5 MHz transducer was placed on the midline in the transverse plane, ~1 cm above the umbilicus, during the expiratory phase, without applying pressure on the abdomen. Subcutaneous fat thickness was measured as the distance (in centimeters) between the skin and the anterior surface of the linea alba. VFT was measured as the distance (in centimeters) between the posterior surface of the linea alba and the plane of the posterior aortic wall. (FIGURE 1).

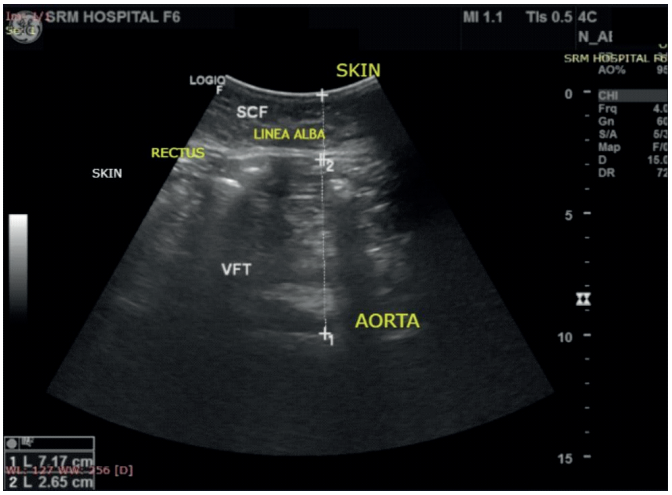

Figure 1 :Visceral Fat Thickness measurement using USG.

All those patients fulfilling inclusion criteria were further proceeded with a collection of personal data which includes age, sex, occupation, drug intake, known cases like Hypertension, Diabetes Mellitus, and hyperlipidaemic states, and finally current and previous illness. Patients' data was distributed into two categories based on VFT as

follows: Category 1: VFT < 6.5 cm Category 2: VFT > 6.5 cm. The collected data was analyzed to determine the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the VFT in predicting the risk of developing metabolic syndrome. The primary outcome of this study was to determine whether visceral fat thickness can be used as a supplementary tool for diagnosing metabolic syndrome.

RESULTS

The study comprised 300 subjects divided into two groups, Group 1 (MS) with 150 patients with metabolic syndrome compared with Group 2 (N) with 150 normal subjects without metabolic syndrome which was taken as control. Both the groups show similar age distributions across the four age categories (20 -30, 31 -40, 41 -50, 51-60) with a non-significant p-value of 0. 853 indicating no statistically significant difference in age distribution between the two groups.

In Group MS, 47.3% of the patients were female and 52.7% were male. In contrast, in Group N, 60. 7% were female, and 39.3% were male. A p-value of 0. 021 indicated a statistically significant difference in gender distribution between the two groups, with more males in the MS group and more females in the N group.

Patients with metabolic syndrome had significantly different physical characteristics compared to a normal group. The MS group had a mean height of 151.42 cm, which is significantly taller than the normal group's mean height of 149.89 cm, with a p-value of 0.019. Additionally, the MS group weighted more on average (74.82 kg) compared to the normal group (62.37 kg), with this difference being highly significant (p < 0.0001). (TABLE 1). Similarly, the mean BMI for the MS group was 32.31, significantly higher than the normal group's mean BMI of 27.73, with a p-value of less than 0.0001. This suggests that individuals with metabolic syndrome were taller, heavier, and had a notably higher BMI compared to those without the condition. (TABLE 2).

The mean HbA1c level in the metabolic syndrome group was 6.60, significantly higher than the 5.76 observed in the normal group, with a p-value of less than 0.0001 indicating a highly significant difference. (TABLE 3). In terms of waist circumference, 67.3% of patients in the MS group had abdominal obesity, while all patients in the normal group had a normal waist circumference, with no abdominal obesity. This difference in waist circumference distribution between the two groups is also highly significant, with a p-value of less than 0.0001, highlighting that waist circumference is notably higher in the MS group. (TABLE 4).

In the metabolic syndrome group, 25.3% of patients had hypertension, while the normal group had no cases of hypertension, with a p-value of less than 0.0001 indicating a highly significant difference. (TABLE 5). Similarly, 60.7% of the MS group had diabetes, whereas none of the normal group patients had diabetes, with a p-value of less than 0.0001 also indicating a highly significant difference. This highlighted a significantly greater prevalence of hypertension and diabetes mellitus in the MS group compared to the normal group.

In Group MS, 44. 7% of the patients had a normal VFT, while 55.3% had visceral obesity. In contrast, all patients in Group N (100. 0%) had normal VFT, and none had visceral obesity. A p-value of less than 0. 0001 indicated a highly significant difference in the VFT distribution between the two groups, with VFT being more in the Metabolic syndrome group. (TABLE 6).

In the metabolic syndrome group, total cholesterol and triglyceride levels were significantly higher compared to the normal group, with fewer patients having normal levels and more having borderline or high levels. The metabolic syndrome group also had a higher percentage of patients with low HDL cholesterol compared to the normal group. However, there was no significant difference in VLDL or LDL cholesterol levels between the two groups.

In this study, Visceral Fat Thickness (VFT) was evaluated as a predictor of metabolic syndrome using a cutoff value of 6.5 cm. Among the 150 patients with metabolic syndrome, 107 had a VFT greater than 6. 5 cm, while 43 had a VFT less than 6.5 cm. In the normal group of 150 patients, 24 had a VFT greater than 6.5 cm, and 126 had a VFT less than 6.5 cm. (FIGURE 2).

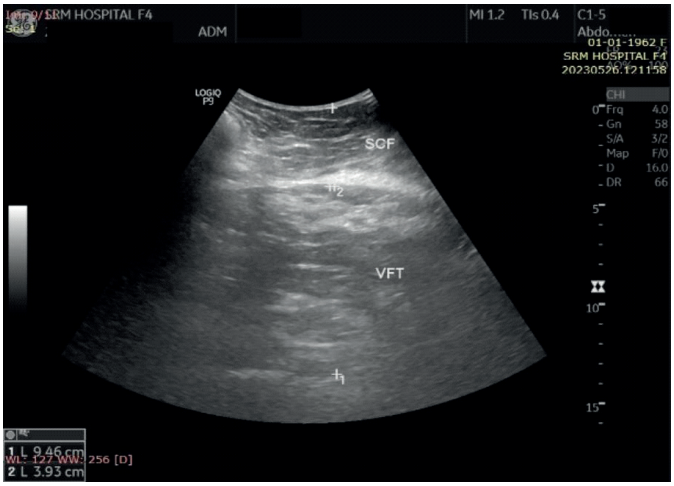

Figure 2 The subject had increased levels of both visceral fat (VFT) (9.4cm) and subcutaneous fat (SCF)(3.9cm). This patient had a normal BMI.

Table 1 Mean Height and Weight in Metabolic Syndrome and Normal Groups.

	GROUP				P-value
	Group MS		Group N		
	Mean	Standard Deviation	Mean	Standard Deviation	
Height (in cm)	151.40	6.27	149.82	5.30	0.019
Weight (in kg)	74.42	13.8	62.37	5.96	<0.0001

Table 2 Mean Basal Metabolic Index in Metabolic Syndrome and Normal Groups

		GROUP				P-value
		Group MS		Group N		
		Count	Column N %	Count	Column N %	
BMI	Normal	0	0.0%	134	89.3%	<0.0001
	Over weight	45	30.0%	16	10.7%	
	Obese	105	70.0%	0	0.0%	

Table 3 HbA1 c levels measurement in Metabolic Syndrome and normal groups

	GROUP				P-value
	Group MS		Group N		
	Mean	Standard Deviation	Mean	Standard Deviation	
HbA1 c	6.60	0.65	5.77	0.27	<0. 0001

a study by .1007/s10654-007-9183-5"Lee-HYPERLINK "https://link.springer.com/article/10.1007/s10654-007-9183-5"ChingHYPERLINK "https://link.springer.com/article/10.1007/s10654-007-9183-5" Hwang examined gender differences in the development of metabolic syndrome using data from a nationwide survey of 5,880 adults in Taiwan. The study concluded that the incidence of Metabolic syndrome was higher in men (20.4%) as compared to women (15.3%). [11]

Table 4 Waist circumference measurement in Metabolic Syndrome and normal groups

		GROUP				P-value
	Group MS		Group N			
	Count	Column N %	Count	Column N %		
WC	Normal	101	67.3%	150	100.0%	<0.0001
	Abdominal obesity (taken >90 cm in males and > 80 cm in females)	49	32.7%	0	0.0%	

Table 5 Hypertension incidence in Metabolic Syndrome and normal groups

		GROUP				P-value
	Group MS		Group N			
	Count	Column N %	Count	Column N %		
HTN	No	112	74.7%	150	100.0%	<0.0001
	Yes	38	25.3%	0	0.0%	

Table 6 Visceral Fat Thickness comparison in Metabolic Syndrome and normal group

Metabolic syndrome		GROUP	
		Normal	
VFT (cm)	>6.5	107	24
	<6.5	43	126

Table 7 ROC analysis values

Cut-off value	6.45
AUC	0.846
P value	<0.0001
Sensitivity	71.33%
Specificity	84.00%
PPV	81.68%
NPV	74.56%
Accuracy	77.67%

DISCUSSION

In this study, Visceral fat thickness was measured in patients with the Metabolic syndrome group and compared with those without the metabolic syndrome.There wasn't any significant difference in age distribution between the groups. The p-value of 0.853 indicates no significant difference in the age distribution between the two groups, suggesting that age was not a confounding factor in the analysis of other parameters.

CORRELATION BETWEEN GENDER AND MS

Our study found a significant difference in gender distribution between the metabolic syndrome (MS) group and the normal group, with a higher proportion of males in the MS group. Supporting this,

CORRELATION BETWEEN HEIGHT, WEIGHT AND BMI WITH MS

Our study found significant differences in height, weight, and BMI between the metabolic syndrome (MS) group and the normal group, with the MS group showing higher values across these measures. Specifically, the MS group had a greater average height, weight, and BMI compared to the normal group, highlighting the association between metabolic syndrome and increased body metrics. Supporting this, Snehalatha et al found that urban Indians with a BMI above 23 kg/m² face a higher risk of diabetes, reflecting that a higher BMI contributes to metabolic syndrome [12]. Another study conducted by Rahmawati et al showed that participants with lower BMI had a lower risk of developing MS (HR = 0.4, 95% CI 0.194–0.919) indicating a 60% lower risk of developing Metabolic Syndrome (MS) compared to those with a normal BMI, while overweight and obese participants were 2.4 and 4.4 times more likely to develop MS (95% CI 1.176–3.320 and 3.345–5.740, respectively) compared to those with normal BMI [13] .

CORRELATION BETWEEN WC AND MS

Central obesity, as assessed by waist circumference (WC), was significantly more prevalent in Group MS (32.7%) compared to Group N (0%), highlighting the association between central obesity and metabolic syndrome. Different studies have used varying WC cutoff values to identify central obesity, with Snehalatha et al suggesting 85 cm for men and 80 cm for women, while our study employed

>90 cm for men and >80 cm for women [12]. Pouliot MC et al found a strong correlation between Waist circumference and visceral fat (r = 0.98), whereas our study observed a medium correlation (r = 0.323)[14]. Hiremath R et al reported high rates of central obesity using similar criteria to ours, reinforcing the importance of WC in assessing metabolic syndrome [15]. Stolk RP et al found WC to be positively correlated with various metabolic risk factors, supporting its role as

Table 8 Comparison with previous studies

Study Aspect	Our Study Findings	Kim et al	Stolk RP et al [5]	Kyung et al.[20]	Hiremath R et al [15]
Visceral Fat Thickness (VFT)	The cutoff was taken at 6. 5 cm. 55.3 % of Group MS patients exhibitedvis-ceral obesity compared to none in Group N (p < 0.0001).	The cutoff was taken at 47.6 mm for men and 35.5 in women. Visceraladipose tissuehad the best correlation with VFT (p< 0.001)	The cut-off taken for VFT was 9. 5 ± 2.5 cm which is higher whencompared to our study.	VFT cutoffs: 58mm to predict CAD and metabolic diseases.	The cutoff value of VFT is not given in this study but instead, it was compared with BMI and WC which showed a significant correlation.
Correlationwith BMI, WC.	Strong correlations with BMI, WC, HbA1c, and triglyceride levels(all p < 0.001).	Strong correlations with BMI, and WC (all p < 0.001).	Similar to our re-search,this study alsodemon-strates that higher waist circumference islinked to increased intraabdominal fat as assessed by USG (p-value < 0.05).	VFT positivelycorre-lated with BMI; waistcircumfer-ence; andserum HDL cholesterol (negatively)	Similar to our research, this study also demonstrates a positive correlation between BMI and VFT. Waist circumference showed a good correlation with BMI,
Lipid Profile	Higher triglyc-eride and lower HDL cholesterol levels in Group MS (both p < 0. 0001). VFT did not correlate significantly with total cholesterol levels(p = 0 .158).	Negative correlation of VFT with HDL	Elevated triglycerides and decreased HDL cholesterol in the vis-ceral obese group were identified Similar to our research, this study also demon-strates that lower HDL cholesterol concen-trations and higher total cholesterol, and triacylglycerol concen-trations were linked to increased intraabdom-inal fat as assessed by USG (p-value < 0. 05).	VFT showed a strong correlation with visceral adipose tissue area (r = 0. 799, P < 0.001), indicating that VFT can effectively estimate visceral fat accumulation. VFT negatively correlat-ed with serum HDL choles-terol.	
GlycemicCon-trol	HigherHbA1c levels in Group MS (6.60 ±0. 65) compared to Group N (5.77 ± 0.27) (p<0.001).	Not specifically mentioned.		Not specifically mentioned.	VFT correlated with blood sugar levels showed a positive but mild correlation (r - 0.0129)
Blood Pressure	HTN is more prevalent in the MS group (25.6 %) as compared to none in normal subjects.	Related positively withHTN (p< 0.001)	A positive associa-tionbetween visceral fat measurements & systolic blood pressure.	Related positively with HTN (p< 0.001	

an independent predictor of metabolic syndrome [5]. Kim SK et al identified WC cutoff values of 88 cm for men and 84.2 cm for women, with WC correlating with triacylglycerol, HDL-cholesterol, and insulin levels, aligning with our findings [16].

CORRELATION BETWEEN HTN AND MS

In our study, in Group MS, 74.7% of the patients did not have hypertension, whereas 25.3% did have the condition. In contrast,

none of the patients in Group N had hypertension. The statistical analysis revealed a p-value of less than 0.0001, indicating a highly significant difference in hypertension prevalence between the two groups and suggesting that patients in the MS group have a markedly higher likelihood of having hypertension compared to those in Group N.

In a study by Catharina AS et al [17] which analyzed 236 hypertensive patients, a high prevalence of metabolic syndrome was observed in both resistant hypertension (73%) and mild-to-moderate hypertension (60%) groups, aligning with our study results and emphasizing the significant association between hypertension and metabolic syndrome.

CORRELATION BETWEEN LIPID PROFILE, HbA1c levels AND MS

In our study of 300 subjects, anthropometric parameters (BMI and waist circumference) showed significant positive correlations with total cholesterol and triglycerides, and negative correlations with HDL, while VLDL and LDL were positively correlated with BMI. Patients with metabolic syndrome had higher HbA1c levels, indicating poorer glycaemic control compared to those without. Supporting studies by Bo Isomaa et al and Guldiken S et al found strong links between metabolic syndrome, insulin resistance, and lipid profile abnormalities, including elevated triglycerides and reduced HDL[18,19] . These findings align with our results and highlight the effectiveness of ultrasonography in assessing visceral fat and its associated cardiovascular risks.

CORRELATION BETWEEN VFT AND MS

In our study, visceral fat thickness (VFT) was shown to be a reliable indicator of visceral fat accumulation and metabolic syndrome, aligning with Kim et al.'s findings that VFT has a strong correlation with visceral adipose tissue area and serves as an effective predictor for metabolic syndrome, although our VFT cutoff was slightly higher [20] . Kyung Kim et al did a study with a VFT cutoff of 58.0 mm whose value is close to our study (6. 5 cm) [16] . They also found a strong correlation between VFT and visceral adipose tissue, suggesting VFT is useful for identifying high-risk diabetic patients and predicting cardiovascular disease. Similarly, Fox CS et al and Stolk RP et al confirmed that visceral adipose tissue (VAT) and intraabdominal fat, respectively, are significantly associated with metabolic risk factors and metabolic syndrome, reinforcing the utility of VFT in assessing metabolic health and cardiovascular risk [5,21] .

ROC ANALYSIS:

The sensitivity, specificity, positive and negative cut-off values for VFT of 6.45 cm and accuracies were 71.33%, 84.00%, and 77.67%, respectively, positive predictive value (PPV) was 81.68%, the negative predictive value was (NPV) 74. 56%. The area under the curve (AUC) was 0. 846, with a p-value of less than 0.0001, indicating good diagnostic performance of the VFT for metabolic syndrome [TABLE 7].

CLINICAL IMPLICATIONS:

Our findings have several clinical implications. The higher prevalence of obesity, dyslipidemia, and abnormal glucose metabolism in patients with metabolic syndrome necessitates early detection and intervention to mitigate cardiovascular risk. Monitoring VFT using USG along with traditional markers such as BMI and WC could enhance risk stratification and guide personalized management strategies.

LIMITATIONS

- No cause/ effect inferences can be drawn from the study.
- Measurements were not grouped into age and gender-based categories.
- The sample size was relatively small.

CONCLUSION

The study identified significant differences between individuals with metabolic syndrome (MS) and those without (N) across various health metrics. MS patients had a higher mean BMI (32.31 kg/m² vs. 27.73 kg/m²), elevated HbA1c levels (6.60% vs. 5.77%), and a notably higher prevalence of abdominal obesity (32.7% vs. 0%). Additionally, MS patients had higher triglyceride levels (171.54 mg/dL vs. 126.05 mg/dL) and 49.3% had low HDL cholesterol, unlike the N group. These findings emphasize the marked metabolic and cardiovascular risks associated with metabolic syndrome, highlighting the importance of these markers for effective risk identification and management through targeted interventions and lifestyle modifications.

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