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Diagnostic Role of Ultrasound Abdominal Fat Index in Detecting Obesity, Hepatic Steatosis, and Metabolic Syndrome Risk

[1]Dr. Mrs. Lovely Kaushal, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

[2]Dr. Swati Goyal, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

[3]Dr. Bhagat Singh Yadav, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

[4]Dr. Nitin Chouhan, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

[5]Dr. Lavanya Vullakulla, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

[6]Dr. Sameer Memon, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

Corresponding Author: Dr. Nitin Chouhan, Department of Radiodiagnosis, Gandhi Medical College & Hamidia Hospital, Bhopal, Madhya Pradesh, India.

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Abstract

Background: Intra-abdominal obesity contributes significantly to metabolic dysfunction and hepatic steatosis. Abdominal Fat Index (AFI), obtained from ultrasonographic measurements of preperitoneal and subcutaneous fat, has emerged as a simple, non-invasive marker of metabolic risk.

Purpose: To evaluate the diagnostic role of AFI in detecting obesity, fatty liver, and associated metabolic comorbidities.

Material and methods: This cross-sectional study included 1634 adults undergoing abdominal ultrasonography. Anthropometric parameters (BMI, waist and hip circumference, waist-to-hip ratio) and metabolic comorbidities were recorded. Preperitoneal and subcutaneous fat thickness were measured to calculate AFI. Fatty liver was graded and statistical analysis were performed.

Results: Of 1634 participants, 67.0% were overweight and 33.0% obese. Fatty liver was detected in 83.7% (Grade (1): 45.7%, Grade (2): 32.4%, Grade (3): 5.6%). Hypertension 39.2% and diabetes 24.9% were most common. AFI increased significantly with fatty liver severity and was higher in obese vs overweight patients

1.03 vs 0.98; $p < 0.001$. AFI correlated positively with BMI, waist circumference, and waist-to-hip ratio. Regression analysis identified waist-to-hip ratio, waist circumference, and BMI as independent predictors of AFI. ROC analysis demonstrated fair discrimination for fatty liver (AUC 0.72, 95% CI 0.687-0.752, $p < 0.001$, with diagnostic accuracy of 84%.

Conclusion: Ultrasound-derived AFI is a reliable, non-invasive marker associated with obesity, fatty liver grading, and metabolic comorbidities, and may serve as a useful screening tool in clinical practice.

Keywords: Abdominal Fat Index; Ultrasonography; Obesity; Fatty Liver; Metabolic comorbidities.

Introduction

Obesity is a major global health challenge characterized by excessive accumulation of adipose tissue, significantly increasing the risk of morbidity and mortality. It is now recognized as a chronic, multifactorial disease influenced by genetic, environmental, socioeconomic, and behavioral factors, including poor dietary habits and physical inactivity [1,2]. The Body Mass Index (BMI), calculated as weight in kilograms divided by the square of height in meters, is widely used for classifying obesity according to World Health Organization (WHO) guidelines [3,4]. While useful for population-level assessments, BMI lacks precision in differentiating lean from fat mass and does not provide information about fat distribution, which is a key determinant of metabolic risk [3,7,21].

To address this limitation, ethnic-specific BMI cut-offs have been proposed, particularly for Asian populations, who exhibit increased susceptibility to obesity-related disorders at lower BMI thresholds than Western populations. Consequently, overweight and obesity are defined at BMI ≥ 23 kg/m² and ≥ 25 kg/m², respectively, for Asian individuals [5,6]. The global burden of obesity has more than doubled in recent decades, now affecting over 43% of adults, including rapid growth in prevalence across middle-income countries [8,9].

This global obesity epidemic has contributed to a parallel increase in non-communicable diseases such as type 2 diabetes, cardiovascular disease, and certain cancers [10–14]. These conditions are mediated by the metabolic and inflammatory disturbances caused by excess fat, including insulin resistance, endothelial dysfunction, and altered adipokine secretion [11,12,37]. Among fat compartments, visceral adipose tissue is particularly pathogenic, being more strongly associated with hypertension, dyslipidemia, and systemic inflammation than subcutaneous fat [12,13]. One hepatic consequence of visceral fat accumulation is metabolic dysfunction-associated fatty liver disease (MAFLD), encompassing a spectrum of liver injury from simple steatosis to fibrosis and cirrhosis [15,16,39].

Although BMI, waist circumference, and waist-to-hip ratio are commonly used anthropometric tools to estimate adiposity, they offer only indirect approximations of visceral fat [17,18,22]. Cross-sectional imaging modalities like computed tomography (CT) and magnetic resonance imaging (MRI) provide precise quantification of intra-abdominal fat but are limited by cost, accessibility, and radiation exposure in the case of CT [18–20,23].

Ultrasonography has gained interest as a viable alternative, offering a safe, cost-effective, and non-invasive method for differentiating preperitoneal and subcutaneous fat layers [26,28,32]. The Abdominal Fat Index (AFI), defined as the ratio of preperitoneal to subcutaneous fat thickness on ultrasound, has emerged as a surrogate marker for intra-abdominal adiposity [19,24,25,27]. It correlates well with visceral fat volumes measured by CT and MRI and has proven feasible for real-time bedside assessments [23,24,29].

AFI has demonstrated clinical utility in predicting metabolic syndrome, hepatic steatosis, insulin resistance, and cardiovascular risk [25,27,29,30,33]. Its relevance has been shown in both adult and pediatric populations and in tracking treatment outcomes [31,34]. Given its simplicity and applicability in low-resource settings, AFI may serve as a practical tool for metabolic risk evaluation [32,36,38].

This study aims to assess the diagnostic value of AFI in individuals meeting obesity criteria by analyzing its correlation with conventional anthropometric measures and ultrasound-based hepatic steatosis grading, thereby evaluating its utility as a screening tool for metabolic risk in obesity [20,26,38].

Materials & Methods

Study Design and Participants

A cross-sectional study was conducted at a tertiary care hospital, between May 2023 and December 2024. Ethical clearance was obtained IEC No: 45/IEC/2023, and informed consent was obtained from all participants. A total of 1,634 consecutive adults undergoing abdominal ultrasonography for routine evaluation were included.

The study included 1634 adults (≥18 years) referred for abdominal ultrasound.

Inclusion Criteria

Adults (>18 years) with BMI ≥25 kg/m² referred for abdominal ultrasound.

Exclusion Criteria

Pregnant women, patients with ascites or hepatic malignancies, or who refused consent.

Data Collection

Anthropometric Assessment

Weight, height, waist and hip circumference were measured to calculate BMI and Waist to Hip Ratio (WHR). Patients were classified as overweight (BMI 25.0-29.9 kg/m²) or obese (BMI ≥30.0 kg/m²).

Ultrasound Protocol

Ultrasound (3.5–5 MHz and 7–12 MHz transducers) was used to measure subcutaneous fat (skin to rectus sheath) and preperitoneal fat (posterior rectus to peritoneum). AFI was calculated as PFT/SFT.

Hepatic steatosis was graded as:

- Grade 0: Normal echogenicity of liver parenchyma
- Grade 1: Mildly increased liver echogenicity as compared to renal cortex with intrahepatic vessel walls and diaphragm are visible
- Grade 2: Moderate increase in liver echogenicity as compared to renal cortex, with partial obscuration of intrahepatic vessel walls.
- Grade 3: Marked echogenicity as compared to renal cortex, with poor or non-visualization of intrahepatic vessels walls and diaphragm.

All ultrasound evaluations were performed by experienced radiologists following standardized protocols.

Metabolic Comorbidities

History of hypertension, diabetes mellitus, coronary artery disease, and hypothyroidism was recorded.

Statistical Analysis

Descriptive statistics were computed. Spearman's correlations assessed associations between AFI and anthropometric measures. One-way ANOVA compared means across fatty liver grades. Independent t-tests compared AFI across BMI categories. Multivariable linear regression identified predictors of AFI. ROC analysis evaluated AFI performance in detecting fatty liver. A p-value <0.05 was considered significant.

Results

Demographic Characteristics

A total of 1,634 patients were included, with a mean age of 44.72 years (SD = 13.75). The largest age group was 41–60 years (44.3%), followed by 21–40 years (39.9%).

Males comprised 54.8% of the study population. A statistically significant association was observed between age group and gender ($p = 0.009$), with males predominating in the 21–60 year range.

Anthropometric Parameters

The mean height was 1.66 m (SD = 0.11), mean weight 82.29 kg (SD = 15.19), and mean BMI 29.63 kg/m² (SD = 3.79). Two-thirds of participants (67.0%) were overweight (BMI 25–29.9 kg/m²) and 33.0% were obese (BMI ≥30.0 kg/m²). The mean waist circumference was 82.02 cm, hip circumference 93.44 cm, and waist-to-hip ratio (WHR) 0.92.

Comorbidities and AFI Association

Hypertension was the most common comorbidity (39.2%), followed by diabetes mellitus (24.9%), coronary artery disease (7.5%), and hypothyroidism (4.4%). AFI showed significant positive associations with diabetes ($\rho = 0.205$, $p < 0.001$) and hypertension ($\rho = 0.220$, $p < 0.001$). AFI was also significantly higher in CAD cases ($p = 0.037$), though the correlation was weak ($\rho = 0.048$, $p = 0.054$). No significant association was observed between AFI and hypothyroidism.

Correlation of Fat Measurements with Anthropometric Indices

AFI correlated positively with BMI ($\rho = 0.226$), waist circumference ($\rho = 0.268$), hip circumference ($\rho = 0.168$), WHR ($\rho = 0.202$), and weight ($\rho = 0.117$), but not with height. Preperitoneal fat thickness showed weak correlations with BMI, WHR, and weight. Subcutaneous fat thickness showed weak negative correlations with waist and hip circumferences.

Fatty Liver Grading and Its Associations

Fatty liver was present in 83.7% of participants: Grade 1 in 45.7%, Grade 2 in 32.4%, and Grade 3 in 5.6%. AFI demonstrated a moderate positive correlation with fatty liver grading ($\rho = 0.545$, $p < 0.001$). Preperitoneal fat thickness correlated weakly ($\rho = 0.249$), whereas subcutaneous fat thickness showed negligible correlation ($\rho = -0.026$). Weight, BMI, waist and hip circumferences, and WHR increased significantly across higher fatty liver grades ($p < 0.001$).

Comparison by BMI Categories

AFI and preperitoneal fat thickness were significantly higher in obese patients (BMI ≥30.0 kg/m²) than in overweight patients (BMI 25.0–29.9 kg/m²) ($p < 0.001$). Subcutaneous fat thickness did not differ significantly between the two groups.

Predictors of Abdominal Fat Index

Regression analysis identified WHR ($\beta = 0.218$, $p < 0.001$), waist circumference ($\beta = 0.177$, $p < 0.001$), BMI ($\beta = 0.144$, $p < 0.001$), and weight ($\beta = 0.047$, $p = 0.041$) as independent predictors of AFI. Height and hip circumference were not predictive. The model explained 9.2% of AFI variance ($R^2 = 0.092$).

Diagnostic Performance of AFI for Fatty Liver

Receiver operating characteristic (ROC) analysis demonstrated fair discrimination of AFI for fatty liver (AUC = 0.720, 95% CI: 0.687–0.752, $p < 0.001$). At the optimal cutoff (0.8548), the overall diagnostic accuracy was 84%, with a Youden's Index of 0.144.

Discussion

This cross-sectional study aimed to investigate the utility of the Abdominal Fat Index (AFI), calculated via ultrasonographic measurements, as a marker of intra-abdominal adiposity and its association with hepatic steatosis and obesity-related comorbidities. The analysis revealed a notable prevalence of fatty liver disease, with Grade 1 steatosis being the most common. A statistically significant relationship was identified between AFI and the severity of fatty liver.

Anthropometric indicators—including body mass index (BMI), waist circumference, hip circumference, and waist-to-hip ratio (WHR)—showed significant positive correlations with both AFI and fatty liver grades. These associations reinforce the relevance of central adiposity in hepatic fat accumulation and are consistent with earlier observations by Ribeiro-Filho et al. and Leite et al. [41–44].

The majority of participants were between 21 and 60 years of age, with a slight predominance of males (54.8%). This demographic distribution closely parallels those reported in studies by Suzuki et al. and Ribeiro-Filho et al. [40,41,44]. While the study population exhibited a relatively lower mean BMI than cohorts comprising morbidly obese individuals, metabolic risks and visceral fat accumulation remained substantial.

Hypertension (39.2%) and diabetes mellitus (24.9%) emerged as the most frequent comorbidities, each showing a significant association with elevated AFI ($p < 0.001$), in agreement with prior reports by Kim et al. and Bertoli et al. (35,48). Coronary artery disease demonstrated only a weak relationship with AFI, and no significant correlation was observed with hypothyroidism.

AFI showed significant positive correlations with body weight, BMI, waist and hip circumferences, and WHR, with the strongest associations noted for waist circumference and WHR, aligning with the findings of Jung et al. and Roopakala et al. [45]. Preperitoneal fat thickness also correlated positively, though less strongly. Conversely, subcutaneous fat thickness exhibited weak or inverse correlations with waist and hip measurements, supporting the view that intra-abdominal fat has greater metabolic relevance than subcutaneous fat [40,45].

Increasing grades of fatty liver corresponded with higher anthropometric and ultrasonographic fat parameters. A moderate positive correlation was observed between AFI and fatty liver severity ($\rho = 0.545$, $p < 0.001$), highlighting its potential as an indirect marker of visceral adiposity. In contrast, subcutaneous fat thickness showed minimal association with hepatic steatosis, reinforcing the role of intra-abdominal fat in the pathogenesis of metabolic dysfunction-associated fatty liver disease (MAFLD) [39, 45].

Individuals with BMI ≥30 kg/m² demonstrated significantly higher mean AFI and preperitoneal fat thickness, underscoring the connection between general obesity and visceral fat accumulation. However, subcutaneous fat did not differ significantly across BMI categories, suggesting its more uniform distribution [40,44].

Regression analysis identified waist-to-hip ratio (WHR), waist circumference, and body mass index (BMI) as independent predictors of the Abdominal Fat Index (AFI), with WHR demonstrating the strongest association ($\beta = 0.218$, $p < 0.001$). Although statistically significant, the model's explanatory power was modest ($R^2 = 0.092$), suggesting that additional factors such as genetic predisposition, physical activity, and dietary habits may contribute to AFI variability.

For the diagnostic performance of AFI in predicting fatty liver, receiver operating characteristic (ROC) analysis yielded an area under the curve (AUC) of 0.720 ($p < 0.001$), indicating fair discriminative ability. A threshold value of 0.8548 was identified, and the ROC analysis confirmed that AFI demonstrated fair discriminatory capacity for detecting fatty liver, with good overall diagnostic accuracy. Given its non-invasive, inexpensive, and reproducible characteristics, AFI may be considered a practical screening parameter in clinical practice, particularly in resource-limited settings.

The present study has certain limitations that should be acknowledged. First, its cross-sectional design restricts the ability to establish causal relationships between abdominal fat distribution, anthropometric indices, and the presence of fatty liver. Second, the study was conducted in a single clinical and geographic setting, which may introduce selection bias and limit the generalizability of the findings to broader populations. Additionally, ultrasonographic assessments are inherently operator-dependent, raising the possibility of inter-observer variability that could influence the reproducibility of measurements.

Based on these limitations, several recommendations can be made. Future multi-center studies involving larger and more diverse populations are warranted to validate the diagnostic performance of the Abdominal Fat Index (AFI) across different ethnic and demographic groups. Given its simplicity, non-invasiveness, and cost-effectiveness, AFI may be considered as a practical screening tool in routine clinical practice for identifying individuals at risk of metabolic syndrome and hepatic steatosis. Incorporating AFI into broader preventive health strategies could aid in the early detection and timely management of metabolic complications.

Conclusions

In conclusion, the Abdominal Fat Index (AFI) is a simple, reliable, and user-friendly ultrasonographic parameter for assessing intra-abdominal fat and its metabolic implications. Its strong correlation with hepatic steatosis, conventional anthropometric indices, and metabolic comorbidities underscores its clinical value in evaluating obesity and metabolic dysfunction–associated fatty liver disease (MAFLD). Beyond individual assessment, AFI enables population-level risk stratification by identifying asymptomatic individuals at increased cardiometabolic risk, particularly when incorporated opportunistically into routine abdominal ultrasound examinations performed for other indications. AFI may thus be adopted as a practical and cost-effective screening tool for the early detection of hepatic steatosis and related metabolic complications.

Abbreviations

- AFI – Abdominal Fat Index
- BMI – Body Mass Index
- WHR – Waist-to-Hip Ratio
- SFT – Subcutaneous Fat Thickness
- PFT – Preperitoneal Fat Thickness
- ROC – Receiver Operating Characteristic
- AUC – Area Under Curve
- MAFLD – Metabolic Dysfunction–Associated Fatty Liver Disease

References

1. Panuganti KK, Nguyen M, Kshirsagar RK. Obesity. [Updated 2023]. In: StatPearls [Internet]. Treasure Island FL: StatPearls Publishing; 2025. Available from: https://www.ncbi.nlm.nih.gov/ books/ NBK459357
2. Purnell JQ. Definitions, classification, and epidemiology of obesity. In: Feingold KR, Anawalt B, Blackman MR, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2000 [cited 2025]. Available from: http:// www. ncbi.nlm.nih.gov/books/NBK279167
3. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Food and Nutrition Board; Roundtable on Obesity Solutions; Callahan EA, editor. Translating knowledge of foundational drivers of obesity into practice: proceedings of a workshop series. Washington (DC): National Academies Press (US); 2023. 10, The science, strengths, and limitations of body mass index. Available from: https:// www.ncbi. nlm.nih.gov/books/NBK594362
4. Weir CB, Jan A. BMI classification percentile and cut off points. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 [cited 2025].

Available from: http://www.ncbi.nlm.nih.gov/books/NBK541070

5. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–163.
6. Tang JW. South Asian American perspectives on overweight, obesity, and the relationship between weight and health. Prev Chronic Dis. 2012;9:E54
7. Nuttall FQ. Body mass index. Nutr Today 2015;50:117–128.
8. World Health Organization. Obesity and overweight [Internet]. [cited 2025]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
9. Boutari C, Mantzoros CS. A 2022 update on the epidemiology of obesity and a call to action: as its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on. Metabolism 2022;133:155217.
10. Scully T, Ettela A, LeRoith D, et al. Obesity, type 2 diabetes, and cancer risk. Front Oncol 2021;10:615375.
11. Rohm TV, Meier DT, Olefsky JM, et al. Inflammation in obesity, diabetes, and related disorders. Immunity 2022;55:31–55.
12. Klein S, Gastaldelli A, Yki-Järvinen H, et al. Why does obesity cause diabetes? Cell Metab 2022;34:11–20.
13. Powell-Wiley TM, Poirier CP, Burke VCLE, et al. Obesity and cardiovascular disease. Circulation 2021;143:e984–1010.
14. Pati S, Irfan W, Jameel A, et al. Obesity and cancer: a current overview of epidemiology, pathogenesis, outcomes, and management. Cancers (Basel) 2023;15:485.
15. Tiwari A, Balasundaram P. Public health considerations regarding obesity. In: StatPearls [Internet]. Treasure Island FL: StatPearls Publishing; 2025 [cited 2025]. Available from: http:// www.ncbi.nlm.nih.gov/books/NBK572122
16. Fabbrini E, Sullivan S, Klein S. Obesity and nonalcoholic fatty liver disease: biochemical, metabolic, and clinical implications. Hepatology 2010;51:679–689.
17. Mahmoud I, Sulaiman N. Significance and agreement between obesity anthropometric measurements and indices in adults: a population-based study from the United Arab Emirates. BMC Public Health 2021;21:1605.
18. Wang H, Chen YE, Eitzman DT. Imaging body fat: techniques and cardiometabolic implications. Arterioscler Thromb Vasc Biol 2014;34:2217–2223.
19. Shuster A, Patlas M, Pinthus JH, et al. The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. Br J Radiol 2012;85:1–10.
20. Carlson-Newberry SJ, Costello RB. Imaging techniques of body composition: advantages of measurement and new uses. In: Emerging technologies for nutrition research: potential for assessing military performance capability [Internet]. Washington, DC: National Academies Press (US); 1997 [cited 2025]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK233794
21. Wu Y, Li D, Vermund SH. Advantages and limitations of the body mass index (BMI) to assess adult obesity. Int J Environ Res Public Health 2024;21:757.
22. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 2008. Geneva: WHO; 2011

23. Klopfenstein BJ, Kim MS, Krisky CM, et al. Comparison of 3 T MRI and CT for the measurement of visceral and subcutaneous adipose tissue in humans. Br J Radiol 2012;85:e826–830.
24. Suzuki R, Watanabe S, Hirai Y, et al. Abdominal wall fat index, estimated by ultrasonography, for assessment of the ratio of visceral fat to subcutaneous fat in the abdomen. Am J Med 1993;95:309–314.
25. Monib AM, Hamed JK, El-Masry ME, et al. Association between abdominal wall fat index (AFI) on ultrasonography with carotid intima media thickness (CIMT) and lipid profile. Med J Cairo Univ 2021;89:1463–1470.
26. Bazzocchi A, Filonzi G, Ponti F, et al. Ultrasound: which role in body composition? Eur J Radiol 2016;85:1469–1480.
27. Shah RV, Murthy VL, Abbasi SA, et al. Visceral adiposity and the risk of metabolic syndrome across body mass index. JACC Cardiovasc Imaging 2014;7:1221–1235.
28. Wagner DR. Ultrasound as a tool to assess body fat. J Obes 2013;2013:280713.
29. Cuatrecasas G, de Cabo F, Coves MJ, et al. Ultrasound measures of abdominal fat layers correlate with metabolic syndrome features in patients with obesity. Obes Sci Pract 2020;6:660–667.
30. Angoorani H, Karimi Z, Naderi F, et al. Is ultrasound-measured abdominal fat thickness a reliable method for predicting metabolic diseases in obese and overweight women? Med J Islam Repub Iran 2018;32:78.
31. Katz B, Bard R, Goldfarb R, et al. Ultrasound assessment of subcutaneous abdominal fat thickness after treatments with a high-intensity focused electromagnetic field device: a multicenter study. Dermatol Surg 2019;45:1542–1548.
32. Silver HJ, Welch EB, Avison MJ, et al. Imaging body composition in obesity and weight loss: challenges and opportunities. Diabetes Metab Syndr Obes 2010;3:337–347.
33. Philipsen A, Jørgensen ME, Vistisen D, et al. Associations between ultrasound measures of abdominal fat distribution and indices of glucose metabolism in a population at high risk of type 2 diabetes: the ADDITION-PRO study. PLoS One 2015;10:e0123062.
34. Novais RLR, Café ACC, Morais AA, et al. Intra-abdominal fat measurement by ultrasonography: association with anthropometry and metabolic syndrome in adolescents. J Pediatr (Rio J) 2019;95:342–349.
35. Kim SK, Kim HJ, Hur KY, et al. Visceral fat thickness measured by ultrasonography can estimate not only visceral obesity but also risks of cardiovascular and metabolic diseases. Am J Clin Nutr 2004;79:593–599.
36. Looney SM, Raynor HA. Behavioral lifestyle intervention in the treatment of obesity. Health Serv Insights 2013;6:15–31.
37. Irving BA, Davis CK, Brock DW, et al. Effect of exercise training intensity on abdominal visceral fat and body composition. Med Sci Sports Exerc 2008;40:1863–1872.
38. Mathew DE, Jayakaran JAJ, Hansdak SG, et al. Cost effective and adaptable measures of estimation of visceral adiposity. Clin Epidemiol Glob Health 2023;23:101362.
39. Boccatonda A, Andreetto L, et al. From NAFLD to MAFLD: definition, pathophysiological basis and

cardiovascular implications. Biomedicines 2023; 11:883.

40. Suzuki R, Watanabe S, Hirai Y, et al. Abdominal wall fat index, estimated by ultrasonography, for assessment of the ratio of visceral fat to subcutaneous fat in the abdomen. Am J Med 1993;95:309–314.
41. Ribeiro-Filho FF, Faria AN, Kohlmann O, et al. Ultrasonography for the evaluation of visceral fat and cardiovascular risk. Hypertension 2001;38:713–717.
42. Leite CC, Wajchenberg BL, Radominski R, et al. Intra-abdominal thickness by ultrasonography to predict risk factors for cardiovascular disease and its correlation with anthropometric measurements. Metabolism 2002;51:1034–1040.
43. Stolk RP, Meijer R, Mali WP, et al. Ultrasound measurements of intraabdominal fat estimate the metabolic syndrome better than do measurements of waist circumference. Am J Clin Nutr 2003;77:857–860.
44. Ribeiro-Filho FF, Faria AN, Azjen S, et al. Methods of estimation of visceral fat: advantages of ultrasonography. Obes Res 2003;11:1488–1494.
45. Jung ED, Chung DS, Lee J. The correlation between visceral fat distance measured by ultrasonography and visceral fat amount by computed tomography in type 2 diabetes. Korean Diabetes J 2008;32:418.

Legend Tables and Figure

Table 1: Baseline characteristics of the study population (n = 1,634)

Parameter	Frequency %
Overweight (BMI 25.0–29.9 kg/m²)	67.0
Obese (BMI ≥30.0 kg/m²)	33.0
Fatty liver present	83.7
Grade 1	45.7
Grade 2	32.4
Grade 3	5.6
Hypertension	39.2
Diabetes mellitus	24.9
Coronary artery disease	7.5
Hypothyroidism	4.4

Table 2: One-way ANOVA showed a significant increase in mean Abdominal Fat Index (AFI) with fatty liver grading (Grade 0: 0.935; Grade 1: 0.974; Grade 2: 1.041; Grade 3: 1.167; F = 319.226, p < 0.001).

Grading of fatty liver	N	Mean Abdominal fat Index	SD	F statistic	P value
Grade 0	267	0.935	0.093	319.226	<0.001
Grade 1	746	0.974	0.067		
Grade 2	529	1.041	0.073		
Grade 3	92	1.167	0.042		

Table 3: Independent t-tests comparing BMI categories (25.0–29.9 vs ≥30.0 kg/m²) showed significantly greater preperitoneal fat thickness (26.02 vs 24.73 mm; $p < 0.001$) and Fat Index (1.03 vs 0.98; $p < 0.001$) in the higher BMI group, while subcutaneous fat thickness did not differ significantly ($p = 0.900$).

Abdominal Fat Indices	BMI Category in kg/m^2	N	Mean	Std. Deviation	t-statistic	p-value
Pre peritoneal Fat (mm)	25.0 – 29.9	1094	24.73	4.23	-5.782	<0.001
	≥30.0	540	26.02	4.26		
Subcutaneous Fat (mm)	25.0 – 29.9	1094	25.17	3.77	-0.126	0.9
	≥30.0	540	25.19	3.79		
Fat Index	25.0 – 29.9	1094	0.98	0.09	-11.182	<0.001
	≥30.0	540	1.03	0.09		

Table 4: Regression and diagnostic performance of AFI

Analysis	Findings	p-value
Regression predictors	Independent predictors: waist-to-hip ratio, waist circumference, BMI	<0.001
Regression model fit	$R^2 = 0.092$	-
ROC analysis	AUC = 0.72 (95% CI 0.687–0.752)	<0.001
Diagnostic accuracy	84% at optimal AFI cutoff	-

Figure 1: ROC curve for AFI to detect fatty liver. AUC = 0.72 (95% CI 0.687–0.752); $p < 0.001$.

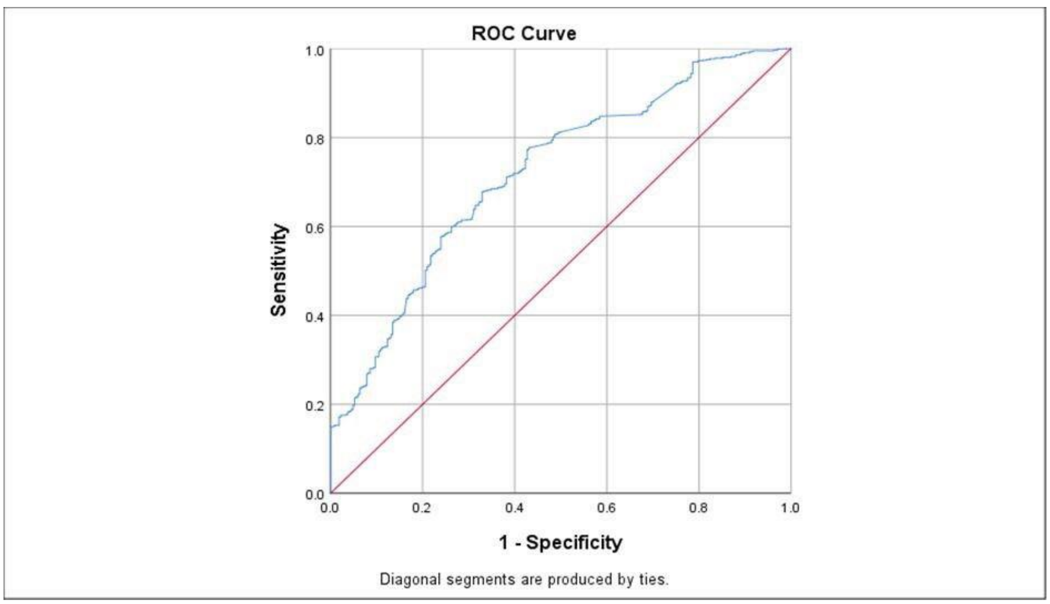

Figure 2: Ultrasound measurement of abdominal fat. Subcutaneous fat thickness (SFT) is measured between the skin and anterior rectus sheath, and preperitoneal fat thickness (PFT) between the rectus muscle and parietal peritoneum. The Abdominal Fat Index (AFI) is calculated as PFT/SFT