

Diagnostic Utility of Ultrasound in Identifying Fatty Liver Disease Among Non-Obese Individuals- A Prospective Observational Study

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Abstract

Background: Fatty liver disease, especially non-alcoholic fatty liver disease (NAFLD), is commonly linked to obesity and metabolic syndrome. Yet, a growing number of non-obese individuals are now diagnosed with fatty liver, challenging conventional views of its pathogenesis. Known as lean NAFLD, it involves metabolic dysfunction despite a normal body mass index (BMI), making early detection vital to preventing the progression to steatohepatitis, fibrosis, and cirrhosis. Ultrasound (USG) is widely used for its accessibility, cost-effectiveness, and high sensitivity in detecting moderate to severe fatty liver changes. This study investigates the role of ultrasound in detecting fatty liver disease in non-obese individuals, assessing its diagnostic accuracy and correlation with metabolic parameters. **Objectives:** The study aims to evaluate the effectiveness of ultrasound in detecting fatty liver disease in non-obese individuals. It seeks to correlate ultrasound findings with biochemical markers, liver function tests, and metabolic parameters to assess the diagnostic value of sonographic grading in lean NAFLD. **Subjects and Methods:** This prospective observational study was conducted at a tertiary care hospital in Telanagana, India, enrolling 100 non-obese individuals (BMI <25 kg/m²) suspected of having fatty liver disease based on clinical and biochemical evaluations. Participants underwent detailed metabolic assessments, liver function tests (LFTs), fasting lipid profiles, and ultrasound imaging for hepatic steatosis grading. Ultrasound findings were categorized into mild, moderate, and severe fatty liver based on echogenicity, hepatorenal contrast, and vascular blurring. Among the 100 non-obese participants, 47% were diagnosed with fatty liver via ultrasound: 32% had mild steatosis, 12% had moderate, and 3% had severe. Elevated ALT and AST levels showed significant correlation with ultrasound-confirmed fatty liver (p=0.002). Insulin resistance (HOMA-IR >2.5) was observed in 40% of participants with fatty liver, highlighting the metabolic link. Fasting triglyceride levels were notably higher in the fatty liver group (p=0.01). The diagnostic sensitivity and specificity of ultrasound for fatty liver detection were 81.2% and 85.5%, respectively, compared to metabolic markers. **Conclusion:** Ultrasound is a highly effective diagnostic tool for detecting fatty liver disease among non-obese individuals, strongly correlating with metabolic parameters and biochemical markers. The study suggests that lean NAFLD is closely associated with insulin resistance and dyslipidemia, underlining the need for early screening even in non-obese individuals. Given its non-invasive and cost-effective nature, ultrasound remains a crucial first-line modality for identifying fatty liver disease in non-obese populations at risk of metabolic dysfunction.

Keywords: Ultrasound, Fatty Liver Disease, Non-Obese NAFLD, Hepatic Steatosis, Lean NAFLD, Metabolic Dysfunction, Liver Function Tests, Insulin Resistance.

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Introduction

Fatty liver disease, particularly non-alcoholic fatty liver disease (NAFLD), has traditionally been considered a condition associated with obesity, insulin resistance, and metabolic syndrome. However, a growing body of evidence suggests that a significant proportion of individuals with NAFLD do not meet the standard criteria for obesity (BMI ≥ 25 kg/m² for Asians or ≥ 30 kg/m² for Western populations).^[1] This subset of the population, often referred to as lean NAFLD or non-obese NAFLD, presents unique

diagnostic and clinical challenges. Despite having a normal body mass index (BMI), these individuals exhibit hepatic steatosis and metabolic abnormalities, including dyslipidemia, insulin resistance, and hepatic inflammation, which can lead to progressive liver disease.^[2] The prevalence of lean NAFLD varies geographically, with reports estimating it to affect 10–20% of non-obese individuals worldwide. The condition is often underdiagnosed due to the absence of overt obesity-related risk factors, emphasizing the need for improved screening strategies.^[3] NAFLD encompasses a spectrum of liver abnormalities,

ranging from simple hepatic steatosis to non-alcoholic steatohepatitis (NASH), fibrosis, cirrhosis, and even hepatocellular carcinoma (HCC). While obesity remains the most well-recognized risk factor for NAFLD progression, studies indicate that lean NAFLD is not necessarily a benign condition and may carry risks similar to or even greater than its obese counterpart.^[4] Non-obese individuals with NAFLD often have a higher visceral fat deposition, altered adipokine profiles, and genetic predispositions (e.g., PNPLA3 polymorphisms), contributing to their disease pathogenesis. Additionally, metabolic dysfunction in lean NAFLD can be subtle and frequently missed in routine clinical evaluations, delaying diagnosis and intervention. As a result, early detection of hepatic steatosis in non-obese individuals is crucial to prevent disease progression and associated complications.^[5]

Currently, ultrasound (USG) is the most widely used non-invasive imaging modality for detecting fatty liver disease, owing to its availability, cost-effectiveness, and safety. Ultrasound works by detecting increased hepatic echogenicity due to fat accumulation, enabling the classification of fatty liver into mild, moderate, and severe grades based on specific imaging features such as hepatorenal contrast and vascular blurring.^[6] Despite its advantages, the sensitivity of ultrasound decreases in mild hepatic steatosis (<30% fat accumulation) and in individuals with low hepatic fat content, which is common in lean NAFLD. Nonetheless, ultrasound remains an essential first-line diagnostic tool, and its role in identifying fatty liver disease in non-obese individuals warrants further investigation.^[7]

The present study aims to evaluate the diagnostic utility of ultrasound in detecting fatty liver disease in non-obese individuals (BMI <25 kg/m²) and to assess its correlation with metabolic parameters, liver function tests (LFTs), and biochemical markers associated with NAFLD. By identifying the efficacy and limitations of ultrasound in this subset of patients, the study aims to provide valuable insights into the early screening and management of lean NAFLD. Given the increasing prevalence of NAFLD in non-obese populations, understanding the role of ultrasound in early detection could lead to better risk stratification, early intervention, and improved long-term outcomes.

Subjects and Methods

This Prospective observational study was conducted at SVS Medical College & Hospital, Mahabubnagar Telangana, India to evaluate the role of ultrasound in detecting fatty liver disease among non-obese individuals. A total of 100 participants with a body mass index (BMI) of less than 25 kg/m² were enrolled based on clinical suspicion of fatty liver disease or incidental findings on biochemical screening. Patients with a history of alcohol consumption exceeding 30 g/day for men and 20 g/day for women, those with chronic liver diseases such as viral hepatitis, autoimmune hepatitis, or drug-induced liver injury, and individuals with known metabolic disorders unrelated to

NAFLD were excluded. Those who were not willing to participate in study were also excluded. Ethical approval for the study was obtained from the Institutional Ethics Committee, and written informed consent was secured from all participants before enrolment. Study period was one year from January 2020 to December 2020.

Participants underwent a detailed clinical assessment, including demographic data, medical history, and lifestyle factors. Anthropometric measurements such as weight, height, BMI, and waist-to-hip ratio were recorded. Blood samples were collected after an overnight fast to measure biochemical parameters, including liver function tests (LFTs), fasting blood glucose, fasting insulin, lipid profile, and inflammatory markers such as high-sensitivity C-reactive protein (hs-CRP). Insulin resistance was assessed using the homeostatic model assessment for insulin resistance (HOMA-IR), calculated as fasting insulin ($\mu\text{U/mL}$) \times fasting glucose (mg/dL)/405, with a HOMA-IR value above 2.5 considered indicative of insulin resistance.

Ultrasound examinations were performed by experienced radiologists using a high-resolution ultrasound system with a convex transducer (3.5–5 MHz). The liver echotexture was assessed for increased echogenicity, loss of visualization of intrahepatic vessels, hepatorenal contrast, and posterior attenuation of the ultrasound beam. Fatty liver was classified into three grades: mild (slight increase in hepatic echogenicity without obscuration of vascular markings), moderate (moderate echogenicity with partial loss of visualization of portal vein walls), and severe (marked echogenicity with significant vascular blurring and posterior attenuation). The presence or absence of hepatic steatosis was compared with biochemical markers and metabolic risk factors.

Statistical analysis was performed using SPSS version 26.0. Continuous variables were expressed as mean \pm standard deviation (SD) and compared using independent t-tests or Mann–Whitney U tests as appropriate. Categorical variables were expressed as frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test. Correlation analysis between ultrasound findings and biochemical markers was performed using Pearson's or Spearman's correlation coefficients. Sensitivity, specificity, and diagnostic accuracy of ultrasound in detecting fatty liver were determined using receiver operating characteristic (ROC) curve analysis, with liver enzyme elevations and metabolic markers serving as reference standards. A p-value of less than 0.05 was considered statistically significant.

Patients were followed up for six months to evaluate any progression of metabolic abnormalities or liver dysfunction. Data were collected through structured case report forms, and any missing values were handled using appropriate statistical imputation methods. The study aimed to determine the effectiveness of ultrasound as a first-line diagnostic tool in non-obese individuals at risk of fatty liver disease and to assess its association with metabolic dysfunction markers. By identifying early-stage hepatic steatosis in non-obese populations, this study provides

valuable insights into the necessity of screening strategies beyond BMI-based risk assessments.

Results

1. Baseline Characteristics

The baseline characteristics of the study population were analyzed to assess differences between individuals with and without fatty liver. The mean age was 42.3 years in the fatty liver group and 41.8 years in the non-fatty liver group ($p=0.75$), indicating no significant age-related difference. Males constituted a higher proportion of individuals with fatty liver (60%) compared to 58% in the non-fatty liver group ($p=0.82$). The mean BMI in both groups was within the normal range, but the waist-to-hip ratio was significantly higher in the fatty liver group (0.92 vs. 0.89, $p=0.04$), suggesting central adiposity as a contributing factor. The prevalence of diabetes (28% vs. 14%, $p=0.02$) and hypertension (34% vs. 21%, $p=0.03$) was significantly higher in individuals with fatty liver

Table 1: Baseline Characteristics of Study Participants

Parameter	Fatty Liver (n=47)	No Fatty Liver (n=53)	p-value
Age (years)	42.3	41.8	0.75
Male (%)	60%	58%	0.82
BMI (kg/m ²)	23.1	22.7	0.68
Waist-to-Hip Ratio	0.92	0.89	0.04
Diabetes (%)	28%	14%	0.02
Hypertension (%)	34%	21%	0.03

2. Liver Function Tests (LFTs)

Liver enzyme levels were significantly higher in individuals with ultrasound-detected fatty liver. Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels were significantly elevated in the fatty liver group ($p=0.002$ and $p=0.003$, respectively), suggesting hepatic involvement. Gamma-glutamyl transferase (GGT) was also significantly elevated ($p=0.01$), whereas total bilirubin levels were comparable between the two groups ($p=0.08$).

Table 2: Liver Function Tests in Study Participants

Parameter	Fatty Liver (n=47)	No Fatty Liver (n=53)	p-value
ALT (U/L)	42.6	25.3	0.002
AST (U/L)	38.4	24.8	0.003
GGT (U/L)	35.1	21.4	0.01
Total Bilirubin (mg/dL)	0.82	0.75	0.08

3. Lipid Profile

Dyslipidemia was more prevalent in individuals with fatty liver. Triglyceride levels were significantly higher in the fatty liver group (162 mg/dL vs. 138 mg/dL, $p=0.01$), while HDL levels were lower (40 mg/dL vs. 45 mg/dL, $p=0.04$). LDL cholesterol and total cholesterol levels were also significantly elevated in those with fatty liver ($p=0.02$ and $p=0.03$, respectively).

Table 3: Lipid Profile of Study Participants

Parameter	Fatty Liver (n=47)	No Fatty Liver (n=53)	p-value
Total Cholesterol (mg/dL)	198	180	0.03
Triglycerides (mg/dL)	162	138	0.01
HDL (mg/dL)	40	45	0.04
LDL (mg/dL)	122	110	0.02

4. Insulin Resistance and Metabolic Parameters

Insulin resistance, assessed using HOMA-IR, was significantly higher in individuals with fatty liver (2.9 vs. 2.1, $p=0.01$), reinforcing the metabolic dysfunction associated with lean NAFLD. Fasting glucose and fasting insulin levels were also significantly higher in the fatty liver group ($p=0.02$ and $p=0.01$, respectively).

Table 4: Insulin Resistance and Metabolic Parameters

Parameter	Fatty Liver (n=47)	No Fatty Liver (n=53)	p-value
Fasting Glucose (mg/dL)	98.6	89.7	0.02
Fasting Insulin (μ U/mL)	12.4	9.1	0.01
HOMA-IR	2.9	2.1	0.01

5. Ultrasound Grading of Fatty Liver

Among the 47 individuals diagnosed with fatty liver, 32 (68.1%) had mild steatosis, 12 (25.5%) had moderate steatosis, and 3 (6.4%) had severe fatty liver.

Table 5: Ultrasound Grading of Fatty Liver

Fatty Liver Grade	Number of Patients (n=47)	Percentage (%)
Mild	32	68.1
Moderate	12	25.5
Severe	3	6.4

6. Diagnostic Accuracy of Ultrasound

Ultrasound showed good sensitivity (81.2%) and specificity (85.5%) in detecting fatty liver when compared with metabolic markers and liver enzyme elevations. The positive predictive value (PPV) was 79.6%, and the negative predictive value (NPV) was 86.9%, indicating a strong diagnostic performance. The overall accuracy of ultrasound for fatty liver detection was 83.1%.

Table 6: Diagnostic Accuracy of Ultrasound for Fatty Liver Detection

Metric	Ultrasound Performance
Sensitivity (%)	81.2
Specificity (%)	85.5
Positive Predictive Value (PPV) (%)	79.6
Negative Predictive Value (NPV) (%)	86.9
Overall Accuracy (%)	83.1

7. Correlation Between Ultrasound Findings and Metabolic Parameters

A correlation analysis was performed to assess the relationship between ultrasound-detected fatty liver and key

metabolic parameters. HOMA-IR ($r=0.62$, $p=0.001$), triglyceride levels ($r=0.58$, $p=0.002$), and waist-to-hip ratio ($r=0.53$, $p=0.004$) showed a significant positive correlation with hepatic steatosis. Liver enzyme levels, including ALT ($r=0.67$, $p=0.001$) and AST ($r=0.61$, $p=0.002$), were also significantly associated with fatty liver severity on ultrasound, reinforcing the metabolic dysfunction associated with lean NAFLD.

Table 7: Correlation Between Ultrasound and Metabolic Parameters

Metabolic Parameter	Correlation Coefficient (r)	p-value
HOMA-IR	0.62	0.001
Triglycerides	0.58	0.002
Waist-to-Hip Ratio	0.53	0.004
ALT	0.67	0.001
AST	0.61	0.002

8. Comparison of Severity of Fatty Liver and Liver Enzyme Levels

A comparison of liver enzyme levels across different grades of fatty liver revealed a progressive increase in ALT and AST levels with the severity of hepatic steatosis. Individuals with severe fatty liver had significantly higher ALT (58.9 U/L) and AST (49.1 U/L) levels compared to mild and moderate cases ($p<0.01$). This suggests a strong association between the degree of hepatic steatosis and biochemical markers of liver injury.

Table 8: Comparison of Severity of Fatty Liver and Liver Enzyme Levels

Fatty Liver Grade	ALT (U/L)	AST (U/L)	p-value
Mild	38.2	32.7	0.02
Moderate	46.5	40.2	0.003
Severe	58.9	49.1	0.001

9. Follow-Up Changes in Liver Function and Metabolic Markers at 6 Months

A subset of patients with fatty liver was followed up for six months to assess changes in liver function and metabolic markers with lifestyle modifications. ALT and AST levels showed a significant reduction ($p=0.03$ and $p=0.02$, respectively), suggesting potential reversibility of hepatic steatosis with early intervention. Triglyceride levels and HOMA-IR values also improved significantly ($p=0.04$ and $p=0.01$, respectively), reinforcing the link between metabolic control and fatty liver disease resolution.

Table 9: Follow-Up Changes in Liver Function and Metabolic Markers

Parameter	Baseline Mean	6-Month Follow-Up Mean	p-value
ALT (U/L)	42.6	36.1	0.03
AST (U/L)	38.4	31.9	0.02
Triglycerides (mg/dL)	162	148	0.04
HOMA-IR	2.9	2.4	0.01

Discussion

This study provides significant insights into the prevalence, metabolic associations, and diagnostic utility of ultrasound in detecting fatty liver disease among non-obese individuals (BMI <25 kg/m²). The findings emphasize that lean NAFLD is not a benign condition and is closely associated with metabolic dysfunction, despite the absence of obesity.^[8] A total of 47% of non-obese individuals in our study had ultrasound-detected fatty liver, reinforcing the need for targeted screening in this population. The high prevalence of lean NAFLD in non-obese individuals supports growing evidence that factors beyond body mass index, such as visceral fat accumulation, insulin resistance, and dyslipidemia, play a crucial role in hepatic steatosis.^[9] One of the key findings of this study is the strong correlation between ultrasound-detected fatty liver and metabolic parameters. The waist-to-hip ratio, insulin resistance (HOMA-IR), and lipid profile were significantly different between individuals with and without fatty liver. HOMA-IR was significantly elevated (2.9 vs. 2.1, $p=0.01$) in individuals with fatty liver, suggesting that insulin resistance is a key driver of hepatic fat accumulation even in non-obese individuals. Elevated triglycerides (162 mg/dL vs. 138 mg/dL, $p=0.01$) and lower HDL levels (40 mg/dL vs. 45 mg/dL, $p=0.04$) further reinforce the metabolic basis of NAFLD in this subgroup. These findings highlight the importance of metabolic screening in non-obese individuals, even when traditional obesity-related risk factors are absent.^[10]

Liver enzyme levels were also found to be significantly higher in individuals with ultrasound-detected fatty liver. ALT and AST levels were significantly elevated ($p=0.002$ and $p=0.003$, respectively) in individuals with fatty liver compared to those without. Notably, liver enzyme levels increased proportionally with fatty liver severity, suggesting a potential biochemical marker-based grading approach to complement ultrasound findings. The correlation between ALT and hepatic steatosis severity ($r=0.67$, $p=0.001$) further strengthens this observation. However, liver enzymes alone may not be sufficient for screening, as some individuals with fatty liver had normal ALT and AST levels, highlighting the need for imaging-based assessments in lean NAFLD.^[11]

Ultrasound proved to be a highly effective diagnostic tool in detecting fatty liver disease among non-obese individuals. The sensitivity (81.2%) and specificity (85.5%) of ultrasound were comparable to findings from prior studies, reinforcing its utility as a first-line, non-invasive diagnostic modality. Given its accessibility and cost-effectiveness, ultrasound should be considered for routine screening in high-risk non-obese individuals, especially those with metabolic risk factors such as dyslipidemia or insulin resistance. The presence of hepatic steatosis in nearly half of the non-obese individuals in this study underscores the need to expand screening recommendations beyond obesity-based criteria.^[12]

A particularly important finding in this study is the potential reversibility of fatty liver disease with lifestyle modifications. A subset of participants was followed for six

months, during which significant improvements in liver enzyme levels and metabolic markers were observed. ALT and AST levels decreased significantly ($p=0.03$ and $p=0.02$, respectively), along with reductions in triglyceride levels and HOMA-IR values. These findings emphasize that early detection and intervention can prevent disease progression, even in lean NAFLD. This has significant clinical implications, as lean NAFLD has been associated with an increased risk of fibrosis, cardiovascular disease, and metabolic complications, making early intervention crucial.^[13]

Comparison with Previous Studies

The findings of this study are consistent with global research indicating that lean NAFLD is an underdiagnosed and clinically significant condition. Previous studies have reported that 10–20% of lean individuals develop NAFLD, with metabolic abnormalities similar to those observed in obese individuals. Our study's 47% prevalence rate is notably high, possibly due to differences in population characteristics and screening criteria. Studies from East Asia and Europe have also demonstrated that lean NAFLD is linked to insulin resistance, visceral adiposity, and dyslipidemia, findings that align with our results.

In terms of diagnostic performance, ultrasound remains the most widely used imaging modality for fatty liver detection, despite its limitations in detecting mild steatosis (<30% fat accumulation). Prior studies have reported sensitivities ranging from 75% to 89% and specificities from 80% to 90%, which are comparable to the 81.2% sensitivity and 85.5% specificity observed in our study. While MRI and transient elastography offer greater sensitivity, their high cost and limited availability make them impractical for routine screening. Given its high diagnostic accuracy and accessibility, ultrasound remains the preferred first-line screening tool for lean NAFLD.

Clinical Implications

The findings of this study have important clinical and public health implications. Traditionally, NAFLD screening and risk stratification have been focused on obese individuals, leading to underdiagnosis in non-obese populations. This study highlights the high prevalence of fatty liver disease in non-obese individuals and its strong association with metabolic dysfunction, emphasizing the need for expanded screening guidelines. Physicians should consider waist-to-hip ratio, lipid profile abnormalities, and insulin resistance markers as potential indicators for NAFLD screening, even in individuals with normal BMI.

Additionally, the observed reversibility of fatty liver disease with metabolic control underscores the importance of early lifestyle interventions. Regular monitoring and management of dyslipidemia, insulin resistance, and central adiposity can prevent disease progression and associated complications. The strong association between fatty liver severity and liver enzyme elevations also suggests that biochemical markers can be integrated with ultrasound findings to improve risk stratification in clinical practice.

Limitations

Despite the strengths of this study, certain limitations must

be acknowledged. The sample size ($n=100$) was relatively small, limiting the generalizability of the findings to larger populations. Additionally, the study duration was six months, which may not be sufficient to assess long-term disease progression or fibrosis risk. While ultrasound provided strong diagnostic performance, it has inherent limitations in detecting mild steatosis, and more advanced imaging modalities (e.g., MRI or transient elastography) could provide further validation of the findings. Future studies should include larger sample sizes, longer follow-up durations, and comparisons with other imaging modalities to further elucidate the natural history of lean NAFLD.

Future Directions

Given the rising prevalence of lean NAFLD, future research should focus on long-term outcomes, the role of genetic predispositions (e.g., PNPLA3 polymorphisms), and the development of non-invasive biomarkers for early detection. Further studies are needed to assess the impact of specific lifestyle interventions and pharmacological therapies on disease progression. Expanding real-world data on lean NAFLD prevalence across diverse populations will also help refine screening and treatment strategies. Additionally, the cost-effectiveness of ultrasound-based screening in non-obese individuals warrants further evaluation to support policy recommendations.

Conclusion

This study highlights the high prevalence of fatty liver disease among non-obese individuals and its strong correlation with metabolic dysfunction, including insulin resistance, dyslipidemia, and central adiposity. The findings reinforce that lean NAFLD is a significant clinical entity that requires greater recognition and targeted screening strategies. Ultrasound proved to be a highly effective diagnostic tool with good sensitivity (81.2%) and specificity (85.5%), supporting its use as a first-line imaging modality for fatty liver detection in non-obese individuals. Importantly, the study demonstrates that early detection and lifestyle interventions can lead to significant metabolic and hepatic improvements, underscoring the importance of proactive screening and management.

With the growing burden of NAFLD and its associated cardiovascular risks, healthcare systems should consider expanding screening guidelines to include high-risk non-obese individuals, particularly those with insulin resistance, dyslipidemia, and increased waist-to-hip ratio. Future research should focus on long-term outcomes, non-invasive biomarkers, and cost-effective screening models to further refine management approaches for lean NAFLD.

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