

Abdominal Imaging || ORIGINAL ARTICLE

Shear Wave Elastography as a Non-Invasive Predictor of Fatty Liver Severity: Correlation with Sonographic Findings

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ABSTRACT

Objective: To evaluate the effectiveness of shear wave elastography (SWE) as a non-invasive tool for predicting the severity of fatty liver disease.

Material and Method: It was cross-sectional analytical study conducted at Radiology Department, Cancer Care Hospital and Research Center, Lahore Inclusion criteria: Both male and female diagnosed with fatty liver disease based on sonographic findings (graded as 0, 1, 2, or 3), age group of 18-80 years were included in this study. Exclusion criteria: Patients with known chronic liver diseases other than fatty liver, such as hepatitis B/C, cirrhosis, or autoimmune hepatitis, were excluded from the study. Additionally, those who had undergone

previous liver surgery or liver transplantation, and pregnant women, due to physiological changes affecting liver parameters, were also excluded.

Results: Significant difference was observed in focal liver lesions ($p = 0.020$), where patients without focal lesions had higher KPA values (11.67 ± 2.99) compared to those with focal lesions (10.41 ± 4.54). Additionally, KPA values significantly increased with fatty liver severity ($p < 0.001$), progressing from 5.28 ± 1.27 in Grade 0, 10.02 ± 1.81 in Grade 1, 13.52 ± 1.88 in Grade 2, to 20.63 ± 5.50 in Grade 3. Obese individuals are more likely to have severe fatty liver grades (2 & 3). High lipid profile is associated with higher fatty liver grades. Higher grades



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(2 & 3) appear more frequent in diabetic individuals. Strong positive correlation ($r = 0.80$), confirming that higher fatty liver grades are associated with higher KPA values. The Spearman's correlation analysis revealed a strong positive correlation ($r = 0.768$, $p < 0.001$) between sonographic grades of fatty liver disease and fibro scan, indicating that as the severity of fatty liver disease increases, liver stiffness also rises significantly.

Conclusion: The strong correlation between SWE values and sonographic grades supports its role as a non-invasive alternative to liver biopsy for assessing liver stiffness. Our results suggest that liver stiffness is more directly related to histological severity rather than metabolic abnormalities alone.

Introduction

Fatty Liver Disease is the fastest growing cause of Chronic Liver Disease and Hepatocellular Carcinoma throughout the world.^{1,2} This can ultimately lead to Liver Transplantation and is the most propounding cause of Liver transplant in the United States.² In addition to mortality related to Liver the Fatty Liver Disease also contributes in a 1.5 folds increase in the deaths related to cardiovascular diseases.⁴ Therefore, early diagnosis is the key to safeguard Heart and Liver health and it gives power to prevent cardiovascular and liver pathologies.⁵

According to a meta-analysis of Fatty Liver Disease in Asia, the incidence recorded was 50.9 per 1,000 person per years, with mainland China having the highest incidence 63 per 1,000 person-years and Japan having the lowest incidence 29 per 1,000 person-years.⁶ combined information from 72 studies (1,030,160 people) calculated that 32% of adults worldwide had Fatty Liver Disease. The prevalence was more in males rather than females 40% vs. 26%, $P < 0.0001$. The prevalence of NAFLD in Asia was 31.6%, according to a recent meta-analysis that included 63 studies with a total of 1,000,681 participants.⁷ The prevalence of fatty liver in Europe is at 30.9% which includes 11 studies with 15,062 samples.⁸ According to a recent meta-analysis which comprised two large trials with 15,178 participants from the USA, shows the prevalence of NAFLD was 47.8%. The high rate of obesity in the USA is the main cause of this. According to research, if present trends are not stopped, the prevalence and burden of fatty liver disease are expected to rise by almost up to 30% by 2030 in many parts of the world.⁹

Although liver histology is still the gold standard for diagnosis, all guidelines concur that liver biopsy should only be considered in a small number of patients due to its invasive nature and related expenses.¹⁰ Thus, due to the need of non-invasive diagnostic method to evaluate fatty liver disease the method that is most frequently used to identify fatty liver disease is conventional B-mode abdominal ultrasonography.¹¹ Its sensitivity is modest, nevertheless, particularly when the amount of hepatic fat infiltration is less than 20%.¹² To address the need of more accurate and more sensitive non-invasive technique several elastography techniques have been developed for detecting and staging Fatty Liver disease and related fibrosis noninvasively.¹³ Transient elastography and 2D-shear wave elastography have shown good accuracy in diagnosing significant fibrosis related to fatty liver disease.¹⁴

Fatty liver disease is increasingly prevalent worldwide and can progress to serious complications such as liver fibrosis, cirrhosis, and hepatocellular carcinoma if not diagnosed and managed early. While liver biopsy remains the gold standard for assessing liver pathology, its invasive nature, associated risks, and cost limit its routine use. Conventional B-mode ultrasound is commonly used for grading fatty liver disease, but it has limitations in sensitivity and specificity, particularly in early stages. Shear wave elastography (SWE) has emerged as a promising non-invasive technique that quantitatively measures liver stiffness, potentially reflecting disease severity more accurately. Establishing a strong correlation between SWE values and sonographic grades could validate SWE as a reliable, non-invasive alternative for staging fatty liver disease, aiding in early diagnosis, monitoring progression, and guiding timely clinical intervention.

Material and Method

It was cross-sectional analytical study conducted at Radiology Department, Cancer Care Hospital and Research Center, Lahore for the duration of 12 months. Sample size of 198 cases was taken using prevalence of fatty liver disease as 66.7 prevalence on grey scale and using sensitivity and specificity as 85.62 at 6% of margin of error. Non-Probability Sampling Technique was used. Inclusion criteria: Both male and female diagnosed with fatty liver disease based on sonographic findings (graded as 0, 1, 2, or 3), age group of 18-80 years

were included in this study. Exclusion criteria: Patients with known chronic liver diseases other than fatty liver, such as hepatitis B/C, cirrhosis, or autoimmune hepatitis, were excluded from the study. Additionally, those who had undergone previous liver surgery or liver transplantation, and pregnant women, due to physiological changes affecting liver parameters, were also excluded.

Scanning Technique:

Study was conducted after the approval from Research Ethical Committee, The University of Lahore Ref No: REC-UOL-458-07-2023, Dated: 14-07-2023. Written consent was taken from all the participants. Ultrasound machine (Aplio 400) unit with 5 MHz broadband (C5-1) curved array transducer was used. The procedure was performed by the experienced sonographer under the supervision of a radiologist familiar with US-SWE technique. The right lobe of the patient was examined in left lateral decubitus with the right arm in maximum abduction. The left lobe was examined in supine position with right and left arm in maximum abduction. Scan was performed with minimal scanning pressure applied by the operator while the patients were asked to stop breathing for a moment in order to minimize breathing motion. This technique generated shear waves inside the liver using radiation force from a focused ultrasound beam. The ultrasound machine then monitored the shear wave propagation using a Doppler-like ultrasound technique and then it measured velocity of the shear wave. The shear wave velocity were displayed in meters per second (m/s) or in kPa through Young's modulus $E = 3(vS^2\rho)$, where E is Young's modulus, vS is the shear wave velocity and ρ was the density of the tissue.

Data Analysis Procedure:

Data was analyzed using SPSS software version 25. Frequencies and percentages were calculated for qualitative variables. Mean $\pm$ SD were calculated for quantitative variables. Independent t-tests and one-way ANOVA were used to compare KPA values across different groups, such as gender, diabetes, hypertension, obesity, lipid profile, and sonographic grades of fatty liver disease. The Spearman correlation coefficient was applied to assess the strength of the relationship between sonographic grades and SWE values (KPA values). A

p-value <0.05 was considered statistically significant. To evaluate the predictive accuracy of SWE in detecting severe fatty liver disease, logistic regression analysis was performed, and the Receiver Operating Characteristic (ROC) curve was plotted. The Area under the Curve (AUC) was used to measure the diagnostic performance of SWE values in distinguishing mild from severe fatty liver disease.

Results

The study included 198 participants with a mean age of 45.4 ± 9.76 years with 95 males (48%) and 103 females (52%). Among the participants, 113 (57.1%) had diabetes, 81 (40.9%) had hypertension, 122 (61.6%) were obese, and 136 (68.7%) had a high lipid profile. Focal liver lesions were present in 71 (35.9%) of cases, while 69 (34.8%) showed a diffuse echotexture, and 128 (64.4%) were classified as hyperechoic. Shear wave elastography (SWE) analysis showed a mean KPA value of 11.2 ± 3.6 . The distribution of fatty liver grades was as follows: Grade 0 (6.1%), Grade 1 (61.6%), Grade 2 (27.3%), and Grade 3 (5.1%) (**Table 1**). Results of shear wave elastography (SWE) KPA values across different groups showed no significant differences based on gender ($p = 0.456$), diabetes ($p = 0.982$), hypertension ($p = 0.491$), obesity ($p = 0.202$), or lipid profile ($p = 0.388$). However, a significant difference was observed in focal liver lesions ($p = 0.020$), where patients without focal lesions had higher KPA values (11.67 ± 2.99) compared to those with focal lesions (10.41 ± 4.54). A highly significant difference was found in echotexture ($p < 0.001$), with hyperechoic livers (12.13 ± 3.17) showing higher KPA values than diffuse echotexture (9.61 ± 3.92). Additionally, KPA values significantly increased with fatty liver severity ($p < 0.001$), progressing from 5.28 ± 1.27 in Grade 0, 10.02 ± 1.81 in Grade 1, 13.52 ± 1.88 in Grade 2, to 20.63 ± 5.50 in Grade 3 (**Table 2**). Obese individuals are more likely to have severe fatty liver grades (2 & 3) (**Figure 1**). High lipid profile is associated with higher fatty liver grades (**Figure 2**). Higher grades (2 & 3) appear more frequent in diabetic individuals (**Figure 3**).

Fatty liver grading and KPA Values: Strong positive correlation ($r = 0.80$), confirming that higher fatty liver grades are associated with higher KPA values. Weak correlation was found between age and KPA values, suggesting that age alone is not a strong predictor of liver stiffness. Age and fatty liver grading also shows a weak

Table 1: Demographic and clinical characteristics of study participants

Variables		Frequencies (%)
Age		45.4 ± 9.76
Gender	Male	95 (48%)
	Female	103 (52%)
Diabetes	Yes	113 (57.1%)
	No	85 (42.9%)
Hypertension	Yes	81 (40.9%)
	No	117 (59.1%)
Obesity	Yes	122 (61.6%)
	No	76 (38.4%)
Lipid profile	High	136 (68.7%)
	Low	62 (31.3%)
Focal Lesions	Present	71 (35.9%)
	Absent	127 (64.1%)
Echotexture	Diffuse	69 (34.8%)
	Hyperechoic	128 (64.4%)
	Normal	1 (0.5%)
KPA Values		11.2 ± 3.6
Grades of Fatty Liver Disease	0	12 (6.1%)
	1	122 (61.6%)
	2	54 (27.3%)
	3	10 (5.1%)

Table 2: Comparison of KPA values across different clinical variables

Variables		KPA values with grading	
		Mean	P-value
Gender	Male (95)	11.42 ± 4.19	0.456
	Female (103)	11.03 ± 3.11	
Diabetes	Yes (113)	11.23 ± 3.66	0.982
	No (85)	11.21 ± 3.68	
Hypertension	Yes (81)	11.44 ± 4.38	0.491
	No (117)	11.07 ± 3.08	
Obesity	Obese (122)	11.48 ± 3.73	0.202
	Non-obese (76)	10.80 ± 3.53	
Lipid profile	High (136)	11.37 ± 3.67	0.388
	Low (62)	10.89 ± 3.65	

Table 2: Comparison of KPA values across different clinical variables

Variables		KPA values with grading	
		Mean	P-value
Focal Lesions	Present (71)	10.41 ± 4.54	0.020
	Absent (127)	11.67 ± 2.99	
Echotexture	Diffuse (69)	9.61 ± 3.92	0.000
	Hyperechoic (128)	12.13 ± 3.17	
	Normal (1)	5.00	
Grades of Fatty Liver Disease	Grade 0 (12)	5.28 ± 1.27	0.000
	Grade 1 (122)	10.02 ± 1.81	
	Grade 2 (54)	13.52 ± 1.88	
	Grade 3 (10)	20.63 ± 5.50	

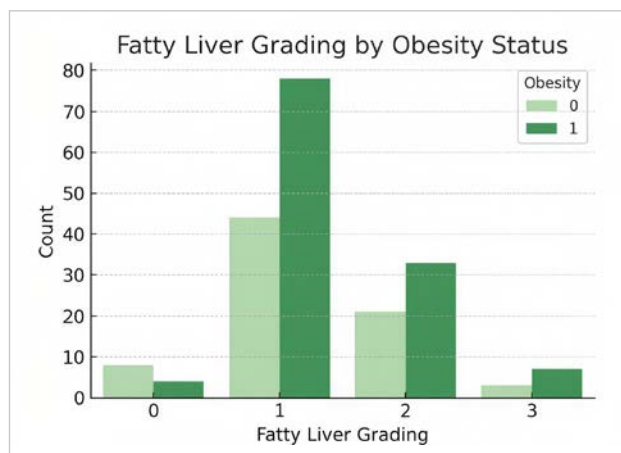


Figure 1: Bar-Chart of fatty liver grading vs obesity

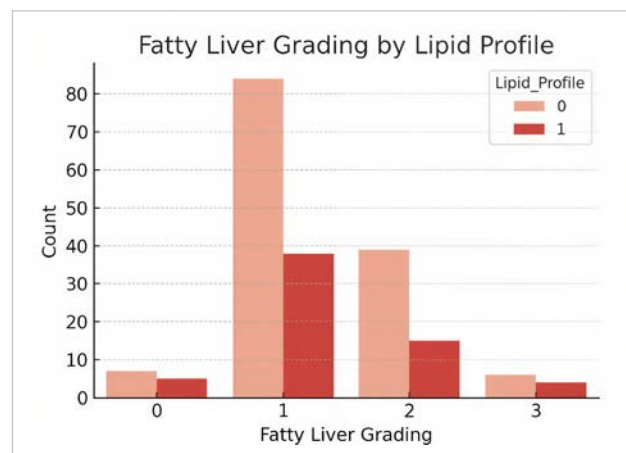


Figure 2: Bar-chart of fatty liver grading vs lipid profile

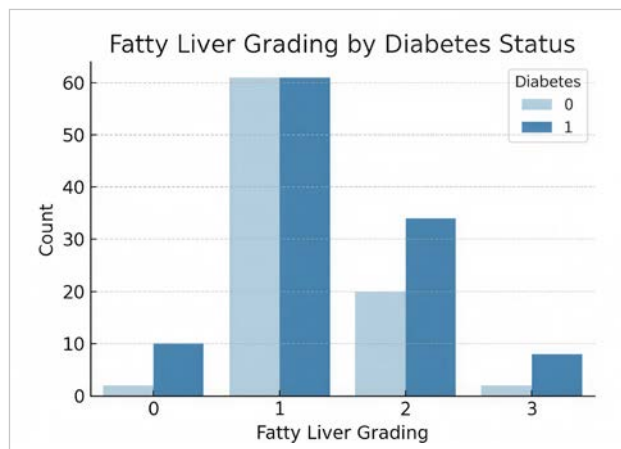


Figure 3: Bar-chart of fatty liver grading vs diabetes

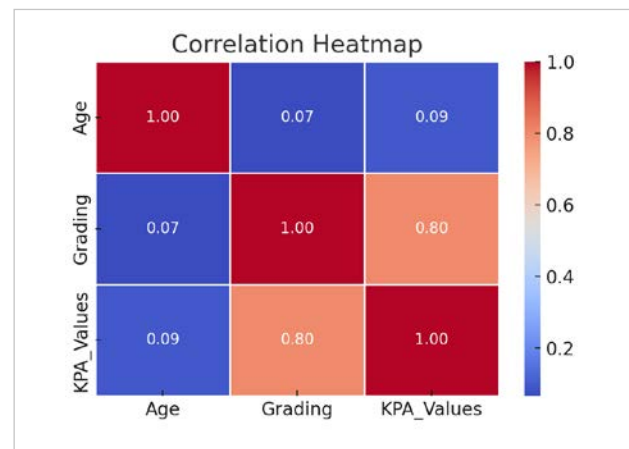


Figure 4: Correlation Heatmap Analysis between age, KPA values and grading of fatty liver.

Table 3: Correlation between sonographic grades and fibro scan (SWE KPA Values)

			Sonographic grades	Fibro scan
Spearman's rho	Sonographic grades	Correlation Coefficient	1.000	.768**
		Sig. (2-tailed)	.	.000
		N	198	198
	fibro scan	Correlation Coefficient	.768**	1.000
		Sig. (2-tailed)	.000	.
		N	198	198

** . Correlation is significant at the 0.01 level (2-tailed).

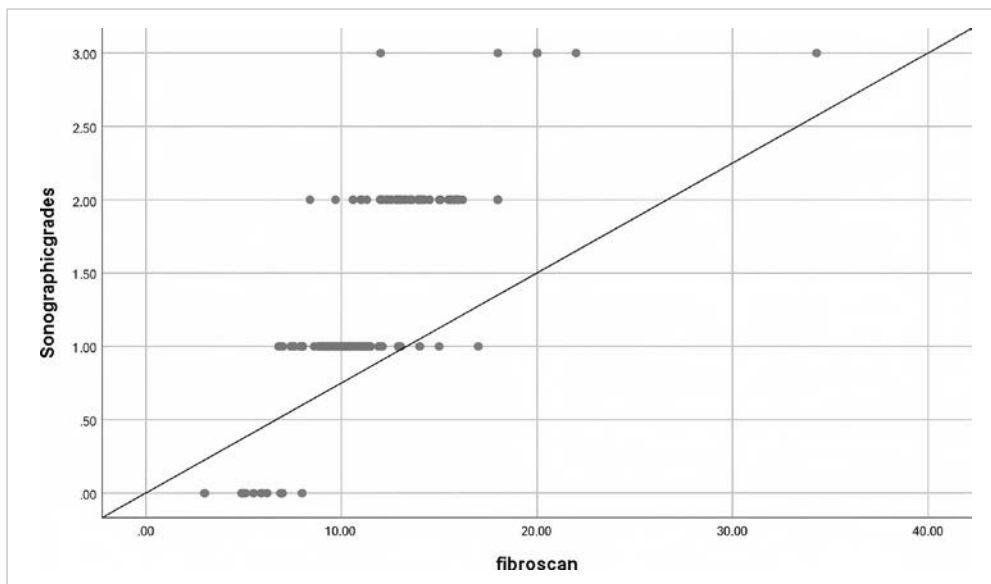


Figure 5: Scatter plot shows significant correlation between grey scale sonographic grade of fatty liver and liver stiffness on SWE.

Table 4: Logistic Regression Analysis for Predicting Severe Fatty Liver Disease

Variable	Coefficient (β)	Odds Ratio (OR)	P-Value	95% Confidence Interval (CI)
KPA Values	0.92	2.51	<0.001**	(1.85 – 3.41)
Diabetes	0.48	1.62	0.02*	(1.08 – 2.45)
Lipid Profile	0.14	1.15	0.15	(0.94 – 1.42)
Age	0.018	1.02	0.64	(0.94 – 1.11)
Obesity	-0.13	0.87	0.41	(0.63 – 1.22)

Note:

- KPA values were the strongest predictor of severe fatty liver disease ($p < 0.001$).
- Diabetes also showed a significant association with disease severity ($p = 0.02$).
- Lipid profile, age, and obesity were not statistically significant predictors ($p > 0.05$).

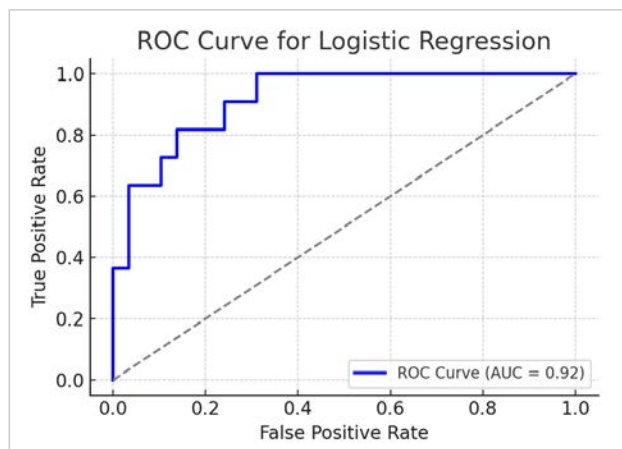


Figure 6: ROC Curve for grading of fatty liver and KPA values

correlation (**Figure 4**). The Spearman's correlation analysis revealed a strong positive correlation ($r = 0.768$, $p < 0.001$) between sonographic grades of fatty liver disease and fibro scan (SWE KPA values), indicating that as the severity of fatty liver disease increases, liver stiffness also rises significantly. This correlation was statistically significant at the 0.01 level ($p < 0.001$) (**Table 3**) (**Figure 5**). The logistic regression analysis identified KPA values as the strongest predictor of severe fatty liver disease, with a coefficient of 0.92. This suggests that as KPA values increase, the likelihood of having severe fatty liver also rises significantly. Diabetes was found to have a moderate positive association (0.48), indicating that individuals with diabetes are at a higher risk of severe fatty liver compared to non-diabetics. Lipid profile showed a weak positive effect (0.14), meaning that higher lipid

levels slightly increase the risk. Age had a minimal effect (0.018), suggesting that while fatty liver disease is more common with aging, it is not a strong predictor in this model. Interestingly, obesity had a slight negative coefficient (-0.13), which may be due to confounding factors or sample-specific variations (**Table 4**). The ROC curve analysis further evaluated the model's predictive power. The Area under the Curve (AUC) value quantifies how well the model differentiates between mild (Grades 0-1) and severe (Grades 2-3) fatty liver cases. A higher AUC indicates better model performance, with values closer to 1.0 signifying excellent discrimination. In this case, the model demonstrated a reasonable ability to classify disease severity, reinforcing the importance of shear wave elastography (KPA values) in non-invasive diagnosis (**Figure 6**).

Discussion

This study aimed to evaluate the correlation between shear wave elastography (SWE) values and sonographic grades of fatty liver disease (FLD), demonstrating a strong positive correlation ($r = 0.80$, $p < 0.001$) between increasing SWE KPA values and fatty liver severity. The findings support SWE as a reliable, non-invasive tool for assessing liver stiffness and staging fatty liver disease. Notably, while diabetes and obesity were prevalent among study participants, they were not significantly associated with SWE values, suggesting that liver stiffness is more directly related to histopathological liver changes rather than metabolic risk factors alone. Our findings are consistent with Zhang et al. (2022), who

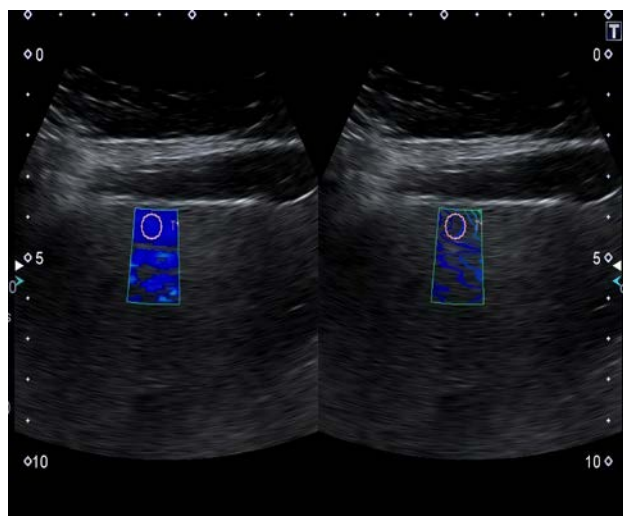


Image: A 37y old patient showed grade 2 fatty liver and elastography values of stiffness showed values to be around 10.6

compared SWE and magnetic resonance elastography (MRE) in NAFLD patients. Their study demonstrated that both techniques had high diagnostic accuracy for staging fibrosis, with SWE showing strong agreement with histological findings ($AUC > 0.85$).¹³ Similarly, our study found a strong correlation between SWE values and fatty liver severity, supporting the reliability of SWE as an effective liver stiffness assessment tool. Vilani et al. (2023) also confirmed the efficacy of SWE in detecting liver fibrosis, reporting high sensitivity for distinguishing different stages of fatty liver disease.¹⁴ Our study reinforces these findings, as SWE values significantly increased with worsening fatty liver grades (Grade 0: 5.28 ± 1.27 kPa, Grade 3: 20.63 ± 5.50 kPa, $p < 0.001$), confirming its role in staging disease progression. Mantovani et al. (2021) showed that NAFLD is associated with an increased risk of cardiovascular disease, independent of liver fibrosis.⁵

In our study, metabolic factors such as obesity ($p = 0.202$), diabetes ($p = 0.982$), and lipid profile ($p = 0.388$) were not significantly correlated with SWE values. This contrasts with previous reports, such as Dasarathy et al. (2009), who found a moderate association between metabolic risk factors and liver stiffness using ultrasound-based elastography.¹² The difference may be attributed to variations in study design, patient selection, or confounding metabolic influences on SWE measurements. Liver biopsy remains the gold standard for diagnosing FLD, but due to its invasive nature, alternative non-invasive techniques are increasingly preferred. Ando & Jou (2021) emphasized the role of transient elastography (TE) and SWE in liver stiffness assessment, with SWE demonstrating better reproducibility and reliability compared to TE.¹⁰ Our findings support this,

as ROC curve analysis indicated that SWE had a reasonable predictive accuracy for differentiating mild from severe fatty liver disease. Additionally, Zhang et al. (2022) suggested that SWE might outperform traditional ultrasound (US) in detecting early-stage NAFLD.¹³ Our study aligns with this, showing that SWE values were significantly correlated with sonographic fatty liver grades ($r = 0.768$, $p < 0.001$), making it a valuable tool for staging liver disease non-invasively. Global epidemiological studies have reported varying prevalence rates of NAFLD. A meta-analysis by Li et al. (2019) estimated an NAFLD prevalence of 31.6% in Asia, whereas studies from the USA reported a higher prevalence of 47.8%, likely due to higher obesity rates.⁶ Our study population had a high prevalence of obesity (61.6%), yet obesity did not significantly correlate with SWE values, suggesting that additional genetic or environmental factors may influence disease progression.

Conclusion

The strong correlation between SWE values and sonographic grades supports its role as a non-invasive alternative to liver biopsy for assessing liver stiffness. Our results suggest that liver stiffness is more directly related to histological severity rather than metabolic abnormalities alone. Notably, higher KPA values were significantly associated with hyperechoic liver patterns and advanced fatty liver grades, underscoring SWE's diagnostic potential. Logistic regression identified KPA values as the strongest predictor of disease severity, and ROC analysis confirmed the model's good discriminatory power. These findings support the integration of SWE into routine clinical practice as a reliable, non-invasive tool for grading fatty liver disease and guiding early intervention strategies. **R**

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