Section: Radiodiagnosis

Original Research Article

ASSESSMENT OF MUSCLE STIFFNESS USING ULTRASOUND ELASTOGRAPHY IN PATIENTS WITH CHRONIC LIVER DISEASE: CORRELATION WITH SARCOPENIA AND LIVER FIBROSIS SEVERITY

Harish Reddy T[1], Khazi Mohammad Athar[2]

[1]*Consultant Radiologist, Kims (Krishna Institute of Mediacl Sciences) Saveera Hospital, India.*
[2]*Junior Resident, Kims (Krishna Institute of Mediacl Sciences) Saveera Hospital, India.*

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Corresponding Author:
Dr. Sumer Singh Shekhawat,
Consultant Radiologist, Kims (Krishna Institute of Mediacl Sciences) Saveera Hospital, India.
Email: harishreddy.t@gmail.com

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ABSTRACT

Background: Chronic liver disease (CLD) is increasingly recognized as a systemic illness with significant extrahepatic manifestations, including sarcopenia. Sarcopenia contributes to higher morbidity, reduced survival, and poorer quality of life in CLD patients. While liver stiffness measurement using ultrasound elastography is established for fibrosis staging, muscle stiffness assessment using shear wave elastography (SWE) offers a novel, non-invasive method to detect early changes in muscle quality. **Aim:** To evaluate quadriceps muscle stiffness using ultrasound SWE in patients with CLD and analyze its correlation with sarcopenia and severity of liver fibrosis.

Materials and Methods: This prospective cross-sectional observational study was conducted in the Department of Radiodiagnosis at KIMS Saveera Hospital. A total of 80 patients with confirmed CLD were enrolled, including 40 sarcopenic and 40 non-sarcopenic individuals based on gait speed assessment. Quadriceps muscle stiffness was measured using 2D-SWE at the mid-thigh level in a relaxed supine position. Liver stiffness was assessed using SWE, and fibrosis was staged according to standard liver stiffness measurement cut-offs. Statistical analysis included comparison of muscle stiffness between groups and correlation analysis between muscle stiffness, gait speed, and liver stiffness.

Results: Sarcopenic patients showed significantly lower quadriceps muscle stiffness compared to non-sarcopenic patients (mean 12.1 ± 2.8 kPa vs 18.2 ± 3.1 kPa, $p < 0.001$). A strong negative correlation was observed between liver stiffness and muscle stiffness ($r = –0.79$, $p < 0.001$), indicating worsening muscle integrity with increasing fibrosis severity. Muscle stiffness also demonstrated a significant positive correlation with gait speed ($p < 0.01$), supporting its association with functional muscle status.

Conclusion: Ultrasound shear wave elastography is a valuable, non-invasive modality for early detection of sarcopenia in patients with CLD. Reduced quadriceps muscle stiffness correlates significantly with sarcopenia and advanced liver fibrosis. Integrating muscle elastography into routine CLD evaluation may enhance risk stratification and enable timely nutritional and rehabilitative interventions.

Keywords: Chronic liver disease; Sarcopenia; Muscle stiffness; Shear wave elastography; Liver fibrosis; Quadriceps muscle; Ultrasound imaging.

INTRODUCTION

Chronic liver disease (CLD) represents a major global health burden and is increasingly recognized as a systemic disorder rather than an isolated hepatic condition. Progressive liver injury leads not only to fibrosis and cirrhosis but also to multiple extrahepatic complications that significantly influence morbidity,

mortality, and quality of life. Among these, sarcopenia—defined as the progressive and generalized loss of skeletal muscle mass, strength, and function—has emerged as a critical and independent prognostic factor in CLD.[1,2]

The pathogenesis of sarcopenia in CLD is multifactorial. Chronic inflammation, hyperammonemia, hormonal imbalance, reduced nutrient intake, altered protein metabolism, and physical inactivity contribute to accelerated muscle protein breakdown and impaired synthesis.[3] Sarcopenia has been associated with increased risk of hepatic decompensation, infections, prolonged hospital stay, poor post-transplant outcomes, and reduced overall survival. Early identification is therefore essential for timely nutritional, pharmacologic, and rehabilitative interventions.[4]

Conventional methods for assessing sarcopenia include cross-sectional imaging (CT or MRI) to estimate muscle mass and functional assessments such as handgrip strength and gait speed. However, these techniques have limitations.[5] Imaging methods may not detect early alterations in muscle quality, and advanced imaging is costly and not always feasible in routine practice. Functional tests, while practical, often detect sarcopenia only after significant muscle deterioration has occurred.

Recent advances in musculoskeletal ultrasound have enabled the evaluation of muscle biomechanics through shear wave elastography (SWE).[6,7] SWE quantifies tissue stiffness by measuring the propagation velocity of shear waves through the tissue. Changes in muscle stiffness may reflect early structural alterations such as fibrosis, fatty infiltration, and reduced elasticity—features that precede visible muscle atrophy. Thus, SWE offers a non-invasive, radiation-free, bedside tool for assessing muscle quality.

Simultaneously, liver stiffness measurement using SWE has become an established non-invasive surrogate for liver fibrosis staging. Considering that liver fibrosis progression and muscle deterioration share common pathophysiological mechanisms, evaluating both parameters in a single imaging session may provide a comprehensive overview of disease burden.[8]

Despite growing interest, limited studies have evaluated the relationship between muscle stiffness and liver fibrosis severity in CLD patients. The present study was therefore designed to assess quadriceps muscle stiffness using SWE and to analyze its association with sarcopenia and liver fibrosis severity.

MATERIALS AND METHODS

This was a prospective cross-sectional observational study designed to evaluate skeletal muscle stiffness in patients with chronic liver disease and correlate it with sarcopenia and liver fibrosis severity. The study was conducted in the Department of Radiodiagnosis at KIMS Saveera Hospital over a period of two months after obtaining institutional ethical clearance. Written informed consent was obtained from all participants prior to enrollment.

A total of 80 adult patients with clinically and radiologically confirmed chronic liver disease were included in the study. Patients were divided into two equal groups:

- Sarcopenic group: 40 patients
- Non-sarcopenic group: 40 patients

Inclusion Criteria

- Age between 18 and 70 years
- Diagnosed case of chronic liver disease based on clinical, laboratory, and imaging findings
- Ability to perform functional assessment (gait speed test)
- Provided informed written consent

Exclusion Criteria

- Acute liver failure
- Known neuromuscular disorders affecting muscle stiffness
- History of recent lower limb trauma or surgery
- Severe hepatic encephalopathy preventing cooperation
- Poor acoustic window for ultrasound examination
- Patients unwilling to participate

Clinical and Functional Assessment

All participants underwent detailed clinical evaluation including history of liver disease duration, etiology, and comorbidities. Functional performance was assessed using gait speed, measured over a standardized walking distance. Based on established cut-offs, patients were categorized into sarcopenic and non-sarcopenic groups.

Ultrasound Elastography Protocol

All examinations were performed using a high-resolution ultrasound system equipped with 2D shear wave elastography capability and a linear high-frequency transducer.

Muscle Stiffness Measurement

- The patient was positioned supine with legs relaxed and slightly extended.
- The quadriceps muscle (rectus femoris) was chosen due to its accessibility and relevance in mobility.
- Measurements were obtained at the mid-thigh level, identified as the midpoint between the anterior superior iliac spine and the superior border of the patella.
- Minimal probe pressure was applied to avoid artificial stiffness changes.
- A region of interest (ROI) was placed within the muscle belly, avoiding fascia and bone.

Three consecutive measurements were taken, and the mean value was recorded in kilopascals (kPa).

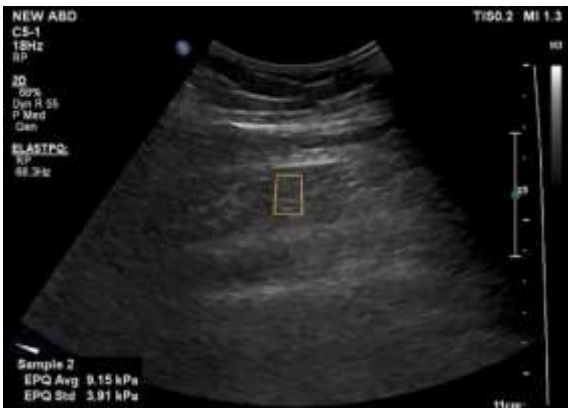

Figure 1:?

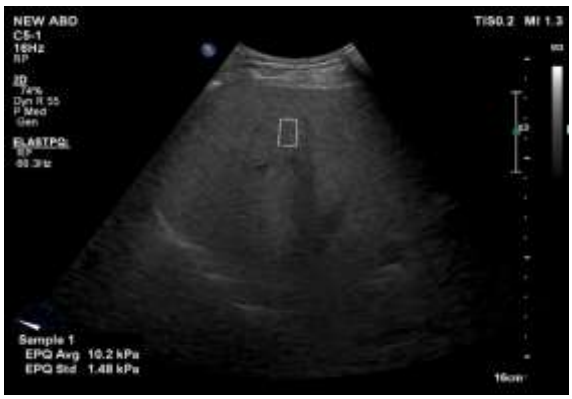

Figure 2:?

Liver Stiffness Measurement

Liver stiffness was measured using SWE with the patient in the supine position and the right arm elevated to widen intercostal spaces.

- Measurements were taken in the right liver lobe through an intercostal approach
- Patients were instructed to hold breath during acquisition
- Multiple valid readings were obtained and averaged
- Liver fibrosis stage was categorized using standard liver stiffness cut-offs (F0–F4)

Data Collection

The following data were recorded: Demographic details (age, sex), Etiology and duration of CLD, Gait speed values, Quadriceps muscle stiffness (kPa), Liver stiffness (kPa) and fibrosis stage

Statistical Analysis

Data were analyzed using statistical software (SPSS 25.0). Continuous variables were expressed as mean ± standard deviation Comparison of muscle stiffness between sarcopenic and non-sarcopenic groups was performed using the independent samples t-test. Correlation between muscle stiffness, liver stiffness, and gait speed was assessed using Pearson's correlation coefficient. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 80 patients with chronic liver disease were included in the study. Based on gait speed assessment, 40 patients were classified as sarcopenic and 40 as non-sarcopenic.

Table 1: Demographic Distribution of Study Population

Variable	Sarcopenic (n=40)	Non-Sarcopenic (n=40)	Total (n=80)
Mean Age (years)	59.8 ± 8.4	54.2 ± 9.1	57.0 ± 9.0
Age >60 years	24 (60%)	14 (35%)	38 (47.5%)
Male	26 (65%)	25 (62.5%)	51 (63.7%)
Female	14 (35%)	15 (37.5%)	29 (36.3%)

Sarcopenic patients were older on average compared to non-sarcopenic patients. Majority of the study population were males (63.7%). Sarcopenia was more frequently observed in patients above 60 years.

Table 2: Functional Assessment – Gait Speed

Parameter	Sarcopenic	Non-Sarcopenic	p-value
Mean Gait Speed (m/s)	0.68 ± 0.09	1.02 ± 0.11	<0.001

Sarcopenic patients had significantly reduced gait speed, confirming impaired functional performance. Gait speed effectively differentiated between sarcopenic and non-sarcopenic groups.

Table 3: Quadriceps Muscle Stiffness (Shear Wave Elastography)

Group	Mean Muscle Stiffness (kPa)	Standard Deviation	p-value
Sarcopenic	12.1	± 2.8	
Non-Sarcopenic	18.2	± 3.1	<0.001

Quadriceps muscle stiffness was significantly lower in sarcopenic patients. This suggests reduced muscle biomechanical integrity in sarcopenia. SWE was sensitive in detecting muscle quality differences even when gross muscle wasting was not obvious.

Table 4: Liver Stiffness and Fibrosis Stage Distribution

Fibrosis Stage	Liver Stiffness Range (kPa)	Sarcopenic (n=40)	Non-Sarcopenic (n=40)
F1 (Mild)	<7.0	4 (10%)	12 (30%)
F2 (Moderate)	7.1–9.5	8 (20%)	14 (35%)
F3 (Advanced)	9.6–12.5	13 (32.5%)	9 (22.5%)
F4 (Cirrhosis)	>12.5	15 (37.5%)	5 (12.5%)

Advanced fibrosis (F3–F4) was more common in sarcopenic patients (70%) than in non-sarcopenic patients (35%).Mild fibrosis stages were predominantly seen in the non-sarcopenic group. Sarcopenia prevalence increased with worsening fibrosis severity.

Table 5: Correlation Between Muscle Stiffness, Liver Stiffness and Gait Speed

Variables Compared	Correlation Coefficient (r)	p-value	Interpretation
Muscle Stiffness vs Liver Stiffness	–0.79	<0.001	Strong negative correlation
Muscle Stiffness vs Gait Speed	+0.66	<0.001	Moderate positive correlation
Liver Stiffness vs Gait Speed	–0.71	<0.001	Strong negative correlation

A strong inverse relationship exists between liver stiffness and muscle stiffness — as fibrosis worsens, muscle stiffness declines. Higher muscle stiffness was associated with better functional performance (faster gait speed). Increased liver stiffness correlated with poorer mobility.

Table 6: Mean Liver Stiffness in Study Groups

Group	Mean Liver Stiffness (kPa)	Standard Deviation	p-value
Sarcopenic	14.8	± 4.2	
Non-Sarcopenic	9.6	± 3.7	<0.001

Sarcopenic patients had significantly higher liver stiffness, indicating more severe fibrosis. This reinforces the systemic link between hepatic disease severity and muscle deterioration.

DISCUSSION

This study evaluated quadriceps muscle stiffness using shear wave elastography (SWE) in patients with chronic liver disease (CLD) and demonstrated a significant association between reduced muscle stiffness, sarcopenia, and liver fibrosis severity. The findings support the concept that CLD is a systemic disorder with parallel deterioration of hepatic and skeletal muscle integrity.

In the present study, 50% of the CLD patients were classified as sarcopenic based on gait speed assessment. This prevalence aligns with previously reported rates of sarcopenia in CLD, which range from 30% to 70% depending on the population studied and diagnostic criteria used. Cruz-Jentoft AJ,[8] and colleagues emphasized that functional parameters such as gait speed are strong predictors of adverse outcomes and are suitable for clinical sarcopenia screening. Our study reinforces the utility of functional assessment in identifying early muscle impairment in CLD patients.

We observed that sarcopenic patients had significantly lower quadriceps muscle stiffness (12.1 ± 2.8 kPa) compared to non-sarcopenic individuals (18.2 ± 3.1 kPa). Reduced muscle stiffness likely reflects structural alterations such as myofibrillar loss, fatty infiltration, and reduced muscle elasticity. Similar observations were reported by Jung K,[9] who demonstrated that SWE-derived muscle stiffness values decrease in chronic liver disease and correlate with muscle weakness. Their work suggested that SWE can detect early muscle quality deterioration even before overt muscle atrophy becomes evident on conventional imaging.

Additionally, Itoh Y found that muscle stiffness values correlated with histological muscle fibrosis and functional impairment, further supporting elastography as a marker of muscle quality rather than merely muscle quantity. Our findings are consistent with these reports and highlight the potential of SWE as a sensitive biomarker of sarcopenia.[10]

A strong negative correlation (r = –0.79) was observed between liver stiffness and muscle stiffness, indicating that increasing fibrosis severity is associated with declining muscle integrity. This relationship likely reflects shared pathophysiological mechanisms including chronic systemic inflammation, hyperammonemia, hormonal dysregulation, and malnutrition, all of which promote muscle catabolism.

Similar findings have been reported in clinical studies where advanced fibrosis and cirrhosis were strongly associated with sarcopenia. Tantai X demonstrated through meta-analysis that sarcopenia significantly increases mortality risk in cirrhotic patients.[11] Moreover, Bajaj JS showed that combining assessments of liver disease severity with muscle health provides superior prognostic value compared to either parameter alone. Our results support this integrated model, showing that worsening liver stiffness parallels deterioration in muscle biomechanical properties.[12]

Muscle stiffness showed a moderate positive correlation with gait speed (r = +0.66), indicating that better muscle elasticity is associated with improved

functional performance. This supports the concept that muscle SWE reflects not only structural changes but also functional capacity. Functional decline is a clinically meaningful endpoint in CLD, as reduced mobility is linked to frailty, falls, hospitalization, and poor survival.[13,14]

The ability to evaluate both liver fibrosis and muscle quality in a single ultrasound session represents a major advantage of SWE. It is non-invasive, radiation-free, widely available, and reproducible. Early detection of muscle quality changes may allow clinicians to initiate nutritional therapy, exercise programs, and metabolic optimization before severe sarcopenia develops.[15]

Conventional imaging techniques primarily assess muscle quantity rather than quality. CT-based muscle area measurement, although considered a reference standard, involves radiation exposure and may not detect early qualitative changes. SWE, by contrast, provides real-time biomechanical assessment, potentially identifying preclinical muscle deterioration. Our study adds to growing evidence that elastography can bridge this diagnostic gap.

Study Limitations

Despite encouraging findings, this study has limitations. The cross-sectional design limits assessment of temporal changes and outcomes. The study was conducted at a single center with a relatively modest sample size. We also did not correlate SWE findings with CT- or MRI-based muscle mass measurements, which could have strengthened validation.

Future Directions

Longitudinal studies are needed to evaluate whether reduced muscle stiffness predicts adverse clinical outcomes such as hepatic decompensation, hospitalization, or mortality. Standardization of muscle SWE protocols and cut-off values will be essential before widespread clinical implementation.

CONCLUSION

This study demonstrates that muscle stiffness measured by ultrasound shear wave elastography is significantly reduced in patients with sarcopenia associated with chronic liver disease. A negative correlation between liver fibrosis severity and quadriceps muscle stiffness was observed, highlighting the interrelation between hepatic and muscular deterioration in CLD. Ultrasound elastography emerges as a simple, non-invasive, and reproducible tool for early detection of sarcopenia, enabling timely nutritional and rehabilitative interventions. Integrating muscle stiffness assessment into routine CLD evaluation may improve risk stratification and clinical outcomes.

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