International Journal of Biomedicine 16(1) (2026) 64-70
http://dx.doi.org/10.21103/Article16(1)_OA8

INTERNATIONAL JOURNAL OF BIOMEDICINE

ORIGINAL ARTICLE

Radiology

Utilizing Ultrasound for Estimating Liver Size in Patients with Fatty Liver Disease: A Study in Jeddah, Saudi Arabia

Salem Alghamdi[1], Abdulrahman Tajaldeen[1*], Rowa Aljondi[1], Abdulrzzag Alghamdi[1], Hamza Showlag[1], Abdulaziz Helabi[1], Samer Ahmed[1], Saeed Al-Malki[1], Talal Al-Omari[1]

[1]Applied Radiologic Technology Department, College of Applied Medical Sciences, University of Jeddah, Jeddah, Saudi Arabia

Abstract

Background: Ultrasound is widely used to evaluate liver morphology in nonalcoholic fatty liver disease (NAFLD), yet the relationships between ultrasound-derived liver size and patient characteristics remain incompletely described in Saudi populations. This study assessed the association between right-lobe liver size and demographic/anthropometric variables among adults with ultrasound-confirmed NAFLD in Jeddah, Saudi Arabia.

Methods and Results: This retrospective, cross-sectional, two-center study included 212 adults (≥18 years) with NAFLD documented on ultrasound reports from 2 tertiary hospitals in Jeddah between 2020 and 2025. The primary outcome was right-lobe liver size (cm) extracted from ultrasound reports and/or PACS measurements. Predictors included sex, age, BMI, and hospital site. Of 212 participants, 114 (53.8%) were female; mean age was 49.5 years, and mean BMI was 31.6 kg/m², with most participants classified as overweight or obese. Mean right-lobe liver size was similar between Hospital A and Hospital B (15.98±2.02 vs 16.07±2.03 cm; *P*=0.763). Females had numerically larger right-lobe measurements than males in both hospitals, but differences were not statistically significant overall (16.18±2.07 vs 15.84±1.94 cm; *P*=0.218). Liver size correlated inversely and weakly with age (r=−0.160, *P*=0.019) and weakly and positively with weight (r=0.221, *P*=0.001) and BMI (r=0.180, *P*=0.009). In multivariable regression adjusting for sex, BMI, and hospital, age remained independently associated with liver size (β=−0.023 cm/year; *P*=0.026), while BMI did not retain significance (β=0.043 cm per kg/m²; *P*=0.110); sex and hospital were not significant predictors.

Conclusion: In adults with ultrasound-reported NAFLD in Jeddah, right-lobe liver size showed modest associations with age and adiposity, with age remaining an independent predictor after adjustment. Sex-based differences were small and non-significant, and measurements were consistent across two hospitals. Standardized acquisition and inclusion of objective NAFLD severity measures (e.g., elastography and laboratory markers) are needed to refine the interpretation of routine ultrasound liver size metrics in regional NAFLD populations.(**International Journal of Biomedicine. 2026;16(1):64-70.**)

Keywords: nonalcoholic fatty liver disease • ultrasound • liver size • right lobe • body mass index • B-mode

For citation: Alghamdi S, Tajaldeen A, Aljondi R, Alghamdi A, Showlag H, Helabi A, Ahmed S, Al-Malki S, Al-Omari T. Utilizing Ultrasound for Estimating Liver Size in Patients with Fatty Liver Disease: A Study in Jeddah, Saudi Arabia. International Journal of Biomedicine. 2026;16(1):64-70. doi:10.21103/Article16(1)_OA8

Introduction

Ultrasound (US) is a diagnostic imaging modality that uses high-frequency sound waves to produce real-time images; it is also referred to as ultrasonography, sonography, and real-time echography.[1] It is preferably used as a diagnostic modality because it is non-invasive, cost-effective, non-ionizing, and widely accessible across medical and clinical settings.[2-4] A sonographer, a person who operates an ultrasound machine, typically uses a handheld probe called a transducer that both emits and receives sound waves.[5] The transducer is placed directly on the patient's skin and moved over the area of interest, emitting sound waves; a computer converts the returning echoes into visual grey-scale images.[3] Diagnostic ultrasound is primarily used to visualize subcutaneous structures and soft tissues, including tendons, muscles, joints, vessels, and internal organs, to

***Corresponding author:** *Dr. Abdulrahman Tajaldeen. E-mail: aatajaldeen@uj.edu.sa*

detect potential pathology or lesions.[6] Air can be a source of artifact during ultrasound imaging, especially in hairy individuals, because it can trap between the transducer and the body; therefore, a water-based gel is used to couple the ultrasound transducer to the patient.[3]

The liver is a large, dense organ situated mainly in the right hypochondrium, spanning the epigastric region and extending into the left hypochondrium toward the left lateral line. Typical liver weight ranges from about 1,400–1,600 g in males and 1,200–1,400 g in females.[7,8] Liver size can vary across many clinical conditions. It may be enlarged in diseases such as hepatitis, alcoholic liver disease, heart failure, and certain metabolic/storage disorders, or decreased in acute fulminant hepatitis and cirrhosis; in some cases, it remains normal. Overall, measuring liver size is a useful diagnostic marker.[7,9] Liver size showed significant associations with sex, age, body mass index (BMI), the presence of fatty liver, and hepatic steatosis grade.[10]

Nonalcoholic fatty liver disease (NAFLD) is among the most prevalent metabolic conditions globally, characterized by abnormal fat buildup in liver cells and potentially progressing to serious complications, including fibrosis, cirrhosis, and hepatocellular carcinoma (HCC).[11-13] NAFLD affects approximately 25% of the global population. Its prevalence is highest in the Middle East (31.79%) and South America (30.45%), while the lowest rates have been reported in Africa (13.48%).[14,15] In 2017, the estimated NAFLD burden was 8,451,000 cases (25.7%) in Saudi Arabia and 255,000 cases (25%) in the UAE. By 2030, NAFLD cases are expected to increase by 48% in Saudi Arabia, reaching 12,534,000, and by 46% in the UAE, reaching 372,000.[16] NAFLD occurs across all sexes, age groups, and ethnicities, and is most strongly associated with obesity, hyperlipidemia, diabetes mellitus, and metabolic syndrome driven by insulin resistance.[17,18]

Ultrasound is an important imaging modality used to assess liver volume, particularly in NAFLD patients.[11,19] It offers a non-invasive approach for evaluating liver size and fat content.[11] Additionally, it enables visualization of liver size and parenchymal texture. Measurements are obtained in multiple planes to ensure accurate liver volume.[17] Studies have demonstrated that B-mode US is effective for identifying moderate-to-severe steatosis, with sensitivity and specificity varying with the degree of fat accumulation.[11,20-24]

Ultrasound B-mode imaging enables a subjective assessment of the extent of fatty infiltration in the liver.[11] The grading of liver steatosis is typically determined using several US features, including liver brightness, liver–kidney contrast, the US appearance of intrahepatic vessels, liver parenchyma, and the diaphragm.[2,11,25] Steatosis is graded as follows: Absent (score 0) when the liver echotexture is normal; mild (score 1), when there is a slight, diffuse increase in liver echogenicity with normal visualization of the diaphragm and the portal vein wall; moderate (score 2), when liver echogenicity is moderately increased with mildly reduced visualization of the portal vein wall and the diaphragm; severe (score 3), when liver echogenicity is markedly increased with poor or absent visualization of the portal vein wall, diaphragm, and the posterior portion of the right liver lobe.[26-29]

This study aims to examine the association between liver size and demographic variables, including gender, age, and BMI, among patients with NAFLD attending healthcare centers in Jeddah, Saudi Arabia. By evaluating ultrasound findings in a representative sample, the study seeks to expand the evidence base on liver disease within the Saudi population. Furthermore, the results may support improved early detection and assist healthcare professionals in developing management strategies tailored to individual patient characteristics.

Methods

Study Design and Setting

This retrospective, cross-sectional study evaluated adult patients who underwent liver ultrasound examinations at two tertiary hospitals in Jeddah, Western Saudi Arabia. Ultrasound and clinical record data were retrieved for examinations performed between 2020 and 2025.

The study included 212 adults aged 18 years or older with ultrasound-based evidence of NAFLD documented in the imaging report.

Inclusion criteria:

Age ≥18 years.

Liver ultrasound performed during 2020–2025 at one of the participating hospitals.

NAFLD reported on ultrasound.

Availability of right lobe liver measurement and core demographic/anthropometric variables (sex, age, weight, height, or BMI).

Exclusion criteria: records indicated alternative causes of hepatic steatosis or liver size alteration (e.g., significant alcohol use if documented, viral hepatitis, known chronic liver disease of other etiology, focal liver mass affecting measurement, prior hepatic surgery/transplantation), pregnancy, or incomplete/uninterpretable ultrasound images/measurements.

Ultrasound Acquisition and Measurement Protocol

All ultrasound examinations were performed as part of routine clinical care at the two participating hospitals. Images and reports were archived in the Picture Archiving and Communication System (PACS). Because this was a retrospective study, a prespecified research acquisition protocol was not implemented, and detailed acquisition parameters (e.g., transducer frequency, exact respiratory phase, and standardized measurement landmarks) were inconsistently documented and therefore could not be fully verified. Right-lobe liver size was extracted from the original clinical documentation (ultrasound report and/or PACS annotations), reflecting the measurements recorded at the time of the examination. When more than one right-lobe measurement was documented, the value labeled as the right-lobe length in the report was used; if multiple right-lobe length values were recorded, the largest documented value was selected for analysis.

Data Sources and Data Collection

Study variables were collected using a structured data extraction sheet. Imaging measurements were obtained from PACS, while demographic and anthropometric data were retrieved from the hospital's electronic medical record system (Oasis). Trained data collectors extracted the data following a predefined coding manual to reduce variability and improve reproducibility.

Variables

Outcome variable: right lobe liver size (cm).

Predictor variables: gender (male/female), age (years), and BMI (kg/m²).

Anthropometric inputs used to compute BMI (when not recorded): weight (kg) and height (m).

Data Management and Quality Control

All data were de-identified before analysis and stored in password-protected files accessible only to the study team. Data cleaning included range checks (e.g., biologically plausible limits for height/weight/BMI and liver size), duplicate removal, and verification of outliers against source records (PACS/EMR). A predefined dataset dictionary was used to ensure uniform data entry.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences SPSS v26. Continuous variables (right-lobe liver size, age, weight, height, and BMI) were summarized as mean ± standard deviation (SD), while categorical variables (sex, age categories, weight categories, height categories, and BMI classifications) were summarized as frequency and percentage. Mean right-lobe liver size was compared between males and females within each hospital (Hospital A and Hospital B) using the independent-samples t-test. Associations between right-lobe liver size and continuous variables (age, weight, height, and BMI) were examined using Pearson's correlation coefficient (r) with two-tailed P-values. A *P*-value <0.05 was considered statistically significant. Records with missing values for the primary outcome (right-lobe measurement) were excluded. For covariates, analyses were performed using complete-case analysis for the variables included in the study.

Results

A total of 212 adults with ultrasound-reported NAFLD were included. As shown in Table 1, Hospital A contributed 109 patients (63/57.8% female and 46/42.2% male), and Hospital B contributed 103 patients (51/49.5% female and 52/50.5% male). Age distribution differed slightly between hospitals; patients aged ≥60 years comprised 19.27% of Hospital A compared with 32.03% of Hospital B (Table 1).

The cohort demonstrated a high metabolic risk profile, with an overall mean BMI of 31.56±7.53 kg/m² (Table 2). Consistent with this, the majority of participants were classified as overweight or obese (Table 1). Specifically, obesity was more frequent in Hospital A (56.88%) than in Hospital B (46.60%), whereas overweight status was more frequent in Hospital B (37.86%) than in Hospital A (24.77%) (Table 1, Figure 1).

Right-lobe liver size estimates by sex and hospital are summarized in Table 3 and visualized in Figure 2. In Hospital A, females demonstrated a larger mean right-lobe liver size than males (16.24±1.77 cm vs. 15.63±2.28 cm), although this difference was not statistically significant (mean difference 0.61 cm, 95% CI −0.19 to 1.41, *P*=0.135). In Hospital B, mean liver size was comparable between females and males (16.11±2.40 cm vs. 16.02±1.59 cm; mean difference 0.08 cm, 95% CI −0.72 to 0.88, *P*=0.836) (Table 3).

Table 1.

Demographic characteristics of patients in Hospital (H) A and B.

Variable	Categories	H-A (n)	H-A (%)	H-B (n)	H-B (%)	Total n(%)
Age (years)	< 20	0	0.00%	1	0.97%	1(0.47%)
	20-29	7	6.42%	3	2.91%	10(4.72%)
	30-39	24	22.02%	19	18.45%	43(20.28%)
	40-49	31	28.44%	29	28.16%	60(28.3%)
	50-59	26	23.85%	18	17.48%	44(20.75%)
	60+	21	19.27%	33	32.03%	54(25.48%)
Total		109	100%	103	100%	212(100%)
Gender	Male	46	42.20%	52	50.49%	98(46.23%)
	Female	63	57.80%	51	49.51%	114(53.77%)
Total		109	100%	103	100%	100%
Weight (kg)	40-49.9	1	0.92%	0	0.00%	1(0.47%)
	50-59.9	5	4.59%	12	11.65%	17(8.02%)
	60-69.9	21	19.27%	16	15.54%	37(17.45%)
	70-79.9	22	20.18%	26	25.24%	48(22.64%)
	80-89.9	23	21.10%	21	20.39%	44(20.76%)
	90-99.9	19	17.43%	11	10.68%	30(14.15%)
	100+	18	16.51%	17	16.50%	35(16.51%)
Total		109	100%	103	100%	212(100%)
Height (m)	1.5-1.599	48	44.0%	40	38.83%	88(41.51%)
	1.6-1.699	36	33.0%	41	39.81%	77(36.32%)
	1.7-1.799	21	19.3%	20	19.42%	41(19.34%)
	1.8-1.899	4	3.7%	2	1.94%	6(2.83%)
Total		109	100%	103	100%	212(100%)
BMI (kg/m²)	Underweight	1	0.92%	0	0.00%	1(0.47%)
	Normal	19	17.43%	16	15.54%	35(16.51%)
	Overweight	27	24.77%	39	37.86%	66(31.13%)
	Obese	62	56.88%	48	46.60%	110(51.89%)
Total		109	100%	103	100%	212(100%)

Table 2.

Continuous variables (mean ± SD) in Hospital A and Hospital B.

Variable	Hospital A	Hospital B
Age (years)	47.94 ± 12.55	51.16 ± 14.13
Weight (kg)	83.18 ± 18.28	81.96 ± 21.12
Height (m)	1.62 ± 0.09	1.62 ± 0.09
BMI (kg/m²)	31.69 ± 6.97	31.41 ± 8.12
Right-lobe liver size (cm)	15.98 ± 2.02	16.07 ± 2.03

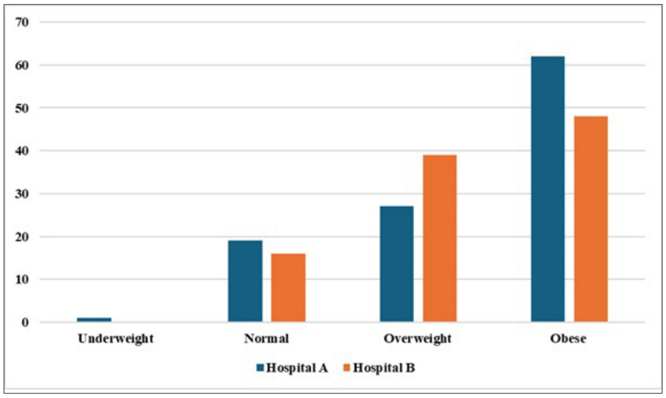

Figure 1. *BMI category distribution by hospital.*

Table 3.

Right-lobe liver size (cm) by sex and hospital, with sex comparisons using independent-samples t-tests.

Comparison	Female (n)	Male (n)	Female mean (cm)	Male mean (cm)	Mean diff (F-M) [95% CI]	*P*-value
Hospital A: Female vs Male	63	46	16.24	15.63	0.61 [-0.19, 1.41]	0.135
Hospital B: Female vs Male	51	52	16.11	16.02	0.08 [-0.72, 0.88]	0.836
Overall: Female vs Male	114	98	16.18	15.84	0.34 [-0.20, 0.89]	0.218

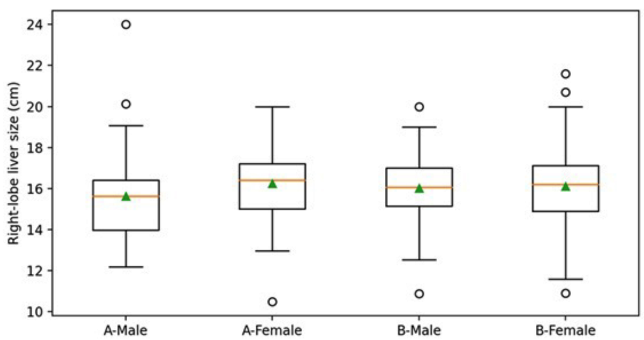

Figure 2. *Right-lobe liver size by sex and hospital (boxplot).*

When both hospitals were pooled, females continued to show a numerically larger mean liver size than males (16.18±2.07 cm vs. 15.84±1.94 cm); however, the between-sex difference remained non-significant (mean difference 0.34 cm, 95% CI −0.20 to 0.89, *P*=0.218) (Table 3).

Across the full sample, mean right-lobe liver size did not differ between hospitals (15.98±2.02 cm in Hospital A vs. 16.07±2.03 cm in Hospital B; *P*=0.763). This finding was consistent in sex-stratified analyses, with no statistically significant hospital-related differences among males (*P*=0.329) or females (*P*=0.746) (hospital comparison output).

As shown in Table 4 and Figure 3, Pearson correlation analysis demonstrated a weak but statistically significant inverse association between age and liver size (r=−0.160, *P*=0.019). Liver size correlated positively and weakly with body weight (r=0.221, *P*=0.001) and BMI (r=0.180, *P*=0.009), while height was not associated with liver size (r=0.031, *P*=0.658) (Table 4).

Table 4.

Pearson correlation between right-lobe liver size and age, weight, height, and BMI.

Predictor	r	*P*-value
Age (years)	-0.16	0.0194
Weight (kg)	0.221	0.0012
Height (m)	0.031	0.6583
BMI (kg/m²)	0.18	0.0087

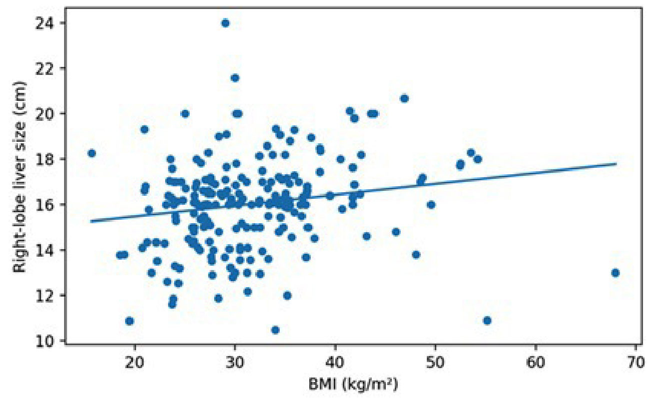

Figure 3. *Association between BMI and right-lobe liver size (scatter plot).*

Multivariable linear regression results are shown in Table 5. After adjustment for sex, BMI, and hospital, age remained independently associated with liver size (β=−0.023 cm/year, 95% CI −0.044 to −0.003, *P*=0.026). BMI showed a positive coefficient but did not reach statistical significance in the adjusted model (β=0.043 cm per 1 kg/m², 95% CI −0.010 to 0.097, *P*=0.110). Sex and hospital were not significant predictors after adjustment (female versus male: P=0.560; Hospital B versus A: *P*=0.515) (Table 5). The model explained a modest proportion of variance in liver size (R^2=0.058, adjusted R^2=0.040).

Table 5.

Multivariable linear regression for predictors of right-lobe liver size (sex, age, BMI, and hospital).

Predictor	Beta (cm)	SE	95% CI	*P*-value
Intercept	15.619	1.052	[13.557, 17.681]	<0.001
Sex (Female vs Male)	0.164	0.281	[-0.387, 0.715]	0.5598
Hospital (B vs A)	0.184	0.282	[-0.369, 0.736]	0.5149
Age (per 1 year)	-0.023	0.01	[-0.044, -0.003]	0.0263
BMI (per 1 kg/m²)	0.043	0.027	[-0.010, 0.097]	0.1095

Discussion

This retrospective two-center study evaluated ultrasound-derived right-lobe liver size in 212 adults with ultrasound-reported NAFLD in Jeddah, Saudi Arabia, and examined associations with sex and demographic/anthropometric variables. The key findings were: (i) females demonstrated numerically larger mean right-lobe measurements than males in both hospitals, although sex differences were not statistically significant; (ii) liver size showed significant positive correlations with weight and BMI and a small inverse correlation with age; and (iii) in multivariable regression including sex, age, BMI, and hospital, age remained independently associated with liver size, whereas BMI did not remain significant after adjustment. These results highlight that ultrasound-measured right-lobe size in NAFLD varies modestly with patient characteristics, and that sex differences may be small and cohort-dependent.

In our cohort, females had a higher mean right-lobe size than males at Hospital A (16.24 vs 15.63 cm) and Hospital B (16.11 vs 16.02 cm), but these between-sex differences were not statistically significant. This contrasts with several studies reporting larger liver dimensions in males, including Dorostghol et al.[10] and earlier reports by Patell et al.,[30] Cruz et al.,[31] and Kratzer et al.[32] Heterogeneity across studies is expected in imaging-based NAFLD research and may reflect differences in cohort composition (age distribution, obesity burden, metabolic comorbidities, and NAFLD severity), as well as variability in ultrasound measurement definitions and technique.[32,33-35] Even when "liver size" is reported, studies may use different planes, landmarks, and respiratory phases, or report linear dimensions rather than volume surrogates, all of which can influence observed sex differences and limit direct comparability.[10,33] Therefore, our results do not necessarily contradict prior evidence but suggest that sex-related differences in ultrasound-measured right-lobe size may not be consistent across NAFLD populations and may be sensitive to both clinical and technical factors.[33,35]

We observed significant positive correlations between liver size and both weight and BMI, aligning with the established relationship between adiposity and NAFLD-related liver enlargement.[10,18,36] However, BMI did not remain statistically significant in the multivariable model, whereas age remained independently associated. This divergence between unadjusted and adjusted analyses is common in clinical datasets and likely reflects shared variance between anthropometric measures and other covariates, as well as residual confounding from unmeasured clinical factors (e.g., diabetes, dyslipidemia, medication exposure, and NAFLD severity).[37] In NAFLD, liver size may reflect not only steatosis-related enlargement but also disease remodeling across the spectrum; without fibrosis staging (e.g., elastography) or biochemical indices, the independent contribution of BMI may be attenuated after adjustment.[33,36] From an imaging standpoint, these findings support interpreting linear liver measurements as part of a broader assessment rather than as a stand-alone marker of disease severity.[18]

Age showed a small inverse association with liver size and remained significant after adjustment. While the effect size was modest, this suggests that liver size may not increase linearly with age in NAFLD cohorts.[10] Age-related variation could reflect differences in metabolic phenotype, disease duration, or the distribution of fibrosis stages.[18,36] For example, advanced fibrosis and architectural remodeling could potentially alter gross liver morphology and may not be captured by a single linear right-lobe measurement.[36] Because fibrosis staging and laboratory markers were not available in this dataset, causal explanations cannot be confirmed; nonetheless, the finding underscores the value of incorporating objective severity assessment (e.g., elastography) in future imaging studies of NAFLD.[33,36]

A strength of this study is the inclusion of two tertiary hospitals and the adjustment for hospital site in the analysis. The findings, therefore, reflect real-world clinical ultrasound reporting across two centers. This cross-site consistency supports the robustness of the observed associations and suggests that the findings are not driven by a single institutional case mix. However, ultrasound measurements remain operator-dependent and can be affected by patient body habitus, transducer selection, scanning plane, and respiratory phase.[10,33,35-36] Future work would be strengthened by explicit reporting of acquisition parameters, a standardized measurement protocol, and reproducibility assessment (intra- and inter-observer agreement), which are particularly valued in imaging journals and facilitate comparison across centers and studies.[33,36]

Clinical Relevance

Ultrasound remains widely used as a first-line imaging modality for suspected hepatic steatosis because it is accessible, noninvasive, and low-cost; however, its sensitivity for mild steatosis is limited, and it cannot stage fibrosis without additional techniques.[10,26,33,34,36-38] In routine abdominal ultrasound reporting, right-lobe size is often available and may provide a supportive context when interpreted alongside steatosis grade, clinical risk profile, and (when available) fibrosis risk stratification tools.[33,36] Our findings suggest that sex-based expectations of liver size may be unreliable in some NAFLD cohorts and underscore the importance of standardized measurement and cautious interpretation, particularly in light of patient-specific characteristics.

Limitations

Several limitations should be acknowledged. First, the retrospective design limited control over ultrasound acquisition conditions and may introduce measurement variability. Second, NAFLD was defined based on ultrasound report documentation without histological confirmation or elastography staging, introducing heterogeneity in disease severity and limiting inference regarding fibrosis-related morphological change. Third, the outcome was a single linear right-lobe measurement rather than true liver volume; linear dimensions may not fully represent three-dimensional liver size. Fourth, important clinical covariates (e.g., diabetes status, lipid profile, liver enzymes, medications, and fibrosis markers) were not available, limiting adjustment for confounding and severity. Finally, although exclusions were intended to reduce alternative causes of hepatomegaly, incomplete documentation is an inherent limitation of retrospective record review.

Future Directions

Prospective multicenter studies in Saudi Arabia should implement standardized ultrasound measurement protocols, document acquisition parameters, and evaluate reproducibility. Integrating elastography with laboratory markers would enable stratification by fibrosis stage and clarify the relationship between linear right-lobe measurements and disease severity. Larger datasets would also allow formal testing of interaction effects (e.g., sex-by-BMI) and development of adjusted reference ranges or prediction models tailored to regional NAFLD populations.[33,34] Where feasible, comparison with MRI- or CT-based volumetry could further validate ultrasound-derived size estimates and improve interpretability in clinical pathways.

Conclusion

In this retrospective two-center study of 212 adults with ultrasound-reported NAFLD in Jeddah, Saudi Arabia, ultrasound-derived right-lobe liver size showed measurable associations with patient characteristics. Mean right-lobe liver size was numerically higher in females than in males in both hospitals; however, sex differences were not statistically significant. Liver size showed a significant but weak correlation with weight and BMI and a weak inverse correlation with age. In multivariable analysis adjusting for sex, BMI, and hospital, age remained independently associated with liver size, whereas BMI did not remain statistically significant. No significant differences in mean liver size were observed between the two hospitals. These findings support the utility of routine ultrasound-based right-lobe measurements as a practical indicator that should be interpreted in the context of demographic and anthropometric factors, and they highlight the need for future multicenter prospective studies incorporating standardized acquisition protocols and objective NAFLD severity measures (e.g., elastography and laboratory markers) to refine clinical interpretation and risk stratification.

Ethical Considerations

The study was conducted in accordance with institutional policies and the Declaration of Helsinki. Ethical approval was obtained from the appropriate institutional review board, and a waiver of informed consent was requested due to the retrospective design and use of de-identified data.

Acknowledgements

First and foremost, we thank Allah for His countless blessings. We also express our sincere gratitude to the University of Jeddah and the College of Applied Medical Sciences for their support. We are especially grateful to Dr. Salem Alghamdi, Dr. Abdulrahman Taj Alden, and Dr. Elbagir Hamza for their valuable guidance and assistance. The authors also thank the technical personnel and staff of the ultrasound departments at all participating hospitals for their support in data collection. Finally, we extend our appreciation to Mr. Meshal Alotaibi for his assistance.

AI Statement

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) for language editing and to articulate research insights effectively. All AI-assisted content was reviewed, verified, and revised by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

Funding Statement

This work was funded by the Deanship of Research and Innovation at the University of Jeddah, Jeddah, Saudi Arabia, under grant No. UJ-22-DR-119.

Competing Interests

The authors declare that they have no conflicts of interest.

References

1. Demirturk Kocasarac H, Angelopoulos C. Ultrasound in Dentistry: Toward a Future of Radiation-Free Imaging. Dent Clin North Am. 2018 Jul;62(3):481-489. doi: 10.1016/j.cden.2018.03.007. PMID: 29903563.
2. Ribeiro R, Sanches J. Fatty liver characterization and classification by ultrasound. Lecture Notes in Computer Science. 2009: 354–361).
3. Azhari H. Ultrasound: medical imaging and beyond (an invited review). Curr Pharm Biotechnol. 2012 Sep;13(11):2104-16. doi: 10.2174/138920112802502033.
4. Wells PN. Physics and engineering: milestones in medicine. Med Eng Phys. 2001 Apr;23(3):147-53. doi: 10.1016/s1350-4533(01)00042-x. PMID: 11410379.
5. Said H. Principles of ultrasonography. J Natl Med Assoc. 1974 May;66(3):205-7, 231.
6. Rumack CM, Levine D. Published by Elsevier Enhanced Digital Version Copyright© 2024. Print ISBN: 9780323877954
7. Singh T, Singla B. Clinical and sonographic estimation of liver span in normal healthy adults. International Journal of Medical Research & Health Sciences. 2017; 6(1): 94-97.
8. Chaurasia BD. Human anatomy: regional and applied upper limb and thorax. CBS Publishers & Distributors. 1984.
9. Rosenfield AT, Laufer I, Schneider PB. The significance of a palpable liver. A correlation of clinical and radioisotope studies. Am J Roentgenol Radium Ther Nucl Med. 1974 Oct;122(2):313-7. doi: 10.2214/ajr.122.2.313.
10. Dorostghol M, Gharibvand MM, Hanafi MG, Motamedfar A. Comparison of size of the liver between patients with non-alcoholic fatty liver disease and healthy controls. J Family Med Prim Care. 2024 Feb;13(2):425-430. doi: 10.4103/jfmpc.jfmpc_94_23.
11. Petzold G. Role of Ultrasound Methods for the Assessment of NAFLD. J Clin Med. 2022 Aug 5;11(15):4581. doi: 10.3390/jcm11154581. PMID: 35956196; PMCID: PMC9369745.
12. European Association for the Study of the Liver (EASL); European Association for the Study of Diabetes (EASD); European Association for the Study of Obesity (EASO). EASL-EASD-EASO Clinical Practice Guidelines for the management of non-alcoholic fatty liver disease. J Hepatol. 2016 Jun;64(6):1388-402. doi: 10.1016/j.jhep.2015.11.004.
13. Simon TG, Roelstraete B, Khalili H, Hagström H,

Ludvigsson JF. Mortality in biopsy-confirmed nonalcoholic fatty liver disease: results from a nationwide cohort. Gut. 2021 Jul;70(7):1375-1382. doi: 10.1136/gutjnl-2020-322786.
14. Chalasani N, Younossi Z, Lavine JE, Charlton M, Cusi K, Rinella M, Harrison SA, Brunt EM, Sanyal AJ. The diagnosis and management of nonalcoholic fatty liver disease: Practice guidance from the American Association for the Study of Liver Diseases. Hepatology. 2018 Jan;67(1):328-357. doi: 10.1002/hep.29367. Epub 2017 Sep 29. PMID: 28714183.
15. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology. 2016 Jul;64(1):73-84. doi: 10.1002/hep.28431. Epub 2016 Feb 22. PMID: 26707365.
16. Alswat K, Aljumah AA, Sanai FM, Abaalkhail F, Alghamdi M, Al Hamoudi WK, Al Khathlan A, Al Quraishi H, Al Rifai A, Al Zaabi M, Babatin MA, Estes C, Hashim A, Razavi H. Nonalcoholic fatty liver disease burden - Saudi Arabia and United Arab Emirates, 2017-2030. Saudi J Gastroenterol. 2018 Jul-Aug;24(4):211-219. doi: 10.4103/sjg.SJG_122_18. Erratum in: Saudi J Gastroenterol. 2018 Jul-Aug;24(4):255. doi: 10.4103/1319-3767.237645.
17. Alsabaani AA, Mahfouz AA, Awadalla NJ, Musa MJ, Al Humayed SM. Non-Alcoholic Fatty Liver Disease among Type-2 Diabetes Mellitus Patients in Abha City, South Western Saudi Arabia. Int J Environ Res Public Health. 2018 Nov 11;15(11):2521. doi: 10.3390/ijerph15112521.
18. Younossi ZM. Review article: current management of non-alcoholic fatty liver disease and non-alcoholic steatohepatitis. Aliment Pharmacol Ther. 2008 Jul;28(1):2-12. doi: 10.1111/j.1365-2036.2008.03710.x.
19. Tamaki N, Ajmera V, Loomba R. Non-invasive methods for imaging hepatic steatosis and their clinical importance in NAFLD. Nat Rev Endocrinol. 2022 Jan;18(1):55-66. doi: 10.1038/s41574-021-00584-0.
20. van Werven JR, Marsman HA, Nederveen AJ, Smits NJ, ten Kate FJ, van Gulik TM, Stoker J. Assessment of hepatic steatosis in patients undergoing liver resection: comparison of US, CT, T1-weighted dual-echo MR imaging, and point-resolved 1H MR spectroscopy. Radiology. 2010 Jul;256(1):159-68. doi: 10.1148/radiol.10091790.
21. Petzold G, Lasser J, Rühl J, Bremer SCB, Knoop RF, Ellenrieder V, et al. Diagnostic accuracy of B-Mode ultrasound and Hepatorenal Index for graduation of hepatic steatosis in patients with chronic liver disease. PLoS One. 2020 May 1;15(5):e0231044. doi: 10.1371/journal.pone.0231044.
22. de Moura Almeida A, Cotrim HP, Barbosa DB, de Athayde LG, Santos AS, Bitencourt AG, de Freitas LA, Rios A, Alves E. Fatty liver disease in severe obese patients: diagnostic value of abdominal ultrasound. World J Gastroenterol. 2008 Mar 7;14(9):1415-8. doi: 10.3748/wjg.14.1415.
23. Lee SS, Park SH, Kim HJ, Kim SY, Kim MY, Kim DY, Suh DJ, Kim KM, Bae MH, Lee JY, Lee SG, Yu ES. Non-invasive assessment of hepatic steatosis: prospective comparison of the accuracy of imaging examinations. J Hepatol. 2010 Apr;52(4):579-85. doi: 10.1016/j.jhep.2010.01.008.
24. Palmentieri B, de Sio I, La Mura V, Masarone M, Vecchione R, Bruno S, Torella R, Persico M. The role of bright liver echo pattern on ultrasound B-mode examination in the diagnosis of liver steatosis. Dig Liver Dis. 2006 Jul;38(7):485-9. doi: 10.1016/j.dld.2006.03.021.
25. Dogra VS, Rubens DJ. Ultrasound secrets. Elsevier Health Sciences, 2004.
26. Ferraioli G, Soares Monteiro LB. Ultrasound-based techniques for the diagnosis of liver steatosis. World J Gastroenterol. 2019 Oct 28;25(40):6053-6062. doi: 10.3748/wjg.v25.i40.6053. PMID: 31686762; PMCID: PMC6824276.
27. Kim SH, Lee JM, Kim JH, Kim KG, Han JK, Lee KH, et al. Appropriateness of a donor liver with respect to macrosteatosis: application of artificial neural networks to US images--initial experience. Radiology. 2005 Mar;234(3):793-803. doi: 10.1148/radiol.2343040142.
28. Hernaez R, Lazo M, Bonekamp S, Kamel I, Brancati FL, Guallar E, et al. Diagnostic accuracy and reliability of ultrasonography for the detection of fatty liver: a meta-analysis. Hepatology. 2011 Sep2;54(3):1082-1090. doi:10.1002/hep.24452.
29. Dasarathy S, Dasarathy J, Khiyami A, Joseph R, Lopez R, McCullough AJ. Validity of real time ultrasound in the diagnosis of hepatic steatosis: a prospective study. J Hepatol. 2009 Dec;51(6):1061-7. doi: 10.1016/j.jhep.2009.09.001. Epub 2009 Sep 20. PMID: 19846234; PMCID: PMC6136148.
30. Patell R, Dosi R, Joshi H, Sheth S, Shah P, Jasdanwala S. Non-Alcoholic Fatty Liver Disease (NAFLD) in Obesity. J Clin Diagn Res. 2014 Jan;8(1):62-6. doi: 10.7860/JCDR/2014/6691.3953.
31. Cruz JF, Cruz MA, Machado Neto J, de Santana DS, Oliveira CC, Lima SO. Prevalence and sonographic changes compatible with fatty liver disease in patients referred for abdominal ultrasound examination in Aracaju, SE. Radiol Bras. 2016 Jan-Feb;49(1):1-5. doi: 10.1590/0100-3984.2014.0124.
32. Kratzer W, Fritz V, Mason RA, Haenle MM, Kaechele V; Roemerstein Study Group. Factors affecting liver size: a sonographic survey of 2080 subjects. J Ultrasound Med. 2003 Nov;22(11):1155-61. doi: 10.7863/jum.2003.22.11.1155.
33. Ozturk A, Kumar V, Pierce TT, Li Q, Baikpour M, Rosado-Mendez I, et al. The Future Is Beyond Bright: The Evolving Role of Quantitative US for Fatty Liver Disease. Radiology. 2023 Nov;309(2):e223146. doi: 10.1148/radiol.223146. .
34. Fetzer DT, Pierce TT, Robbin ML, Cloutier G, Mufti A, Hall TJ, et al. US Quantification of Liver Fat: Past, Present, and Future. Radiographics. 2023 Jul;43(7):e220178. doi: 10.1148/rg.220178. PMID: 37289646.
35. Ballestri S, Romagnoli D, Nascimbeni F, Francica G, Lonardo A. Role of ultrasound in the diagnosis and treatment of nonalcoholic fatty liver disease and its complications. Expert Rev Gastroenterol Hepatol. 2015 May;9(5):603-27. doi: 10.1586/17474124.2015.1007955.
36. Mishra P, Younossi ZM. Abdominal ultrasound for diagnosis of nonalcoholic fatty liver disease (NAFLD). Am J Gastroenterol. 2007 Dec;102(12):2716-7. doi: 10.1111/j.1572-0241.2007.01520.x. PMID: 18042105.
37. European Association for the Study of the Liver (EASL); European Association for the Study of Diabetes (EASD); European Association for the Study of Obesity (EASO). EASL-EASD-EASO Clinical Practice Guidelines for the management of non-alcoholic fatty liver disease. J Hepatol. 2016 Jun;64(6):1388-402. doi: 10.1016/j.jhep.2015.11.004.
38. Chalasani N, Younossi Z, Lavine JE, Charlton M, Cusi K, Rinella M, et al. The diagnosis and management of nonalcoholic fatty liver disease: Practice guidance from the American Association for the Study of Liver Diseases. Hepatology. 2018 Jan;67(1):328-357. doi: 10.1002/hep.29367.