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Research Article

Ultrasonographic Evaluation of Fatty Liver Disease and Its Association with Body Mass Index: A Hospital-Based Observational Study

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Abstract: ***Introduction:*** Fatty liver disease is frequently detected during abdominal ultrasonography and is closely linked to excess adiposity and metabolic abnormalities. Evidence describing the relationship between body mass index and ultrasonographic severity in hospital populations remains clinically useful for risk stratification.**Objectives**: To determine the prevalence and ultrasonographic grades of fatty liver disease and evaluate their association with body mass index among adults undergoing abdominal ultrasonography.**Methods:** This hospital-based cross-sectional observational study included 80 adults evaluated at Konaseema Institute of Medical Sciences & Research Foundation, Amalapuram, Andhra Pradesh, India, from January to June 2020. Demographic characteristics, body mass index, waist circumference, diabetes mellitus, hypertension and dyslipidaemia were recorded. Fatty liver was graded by B-mode ultrasonography. Group differences were examined using independent-samples t-tests and chi-square tests. Spearman correlation and multivariable logistic regression were applied. **Results:** Fatty liver disease was identified in 42 participants (52.5%; 95% confidence interval: 41.7–63.1%). Grade I, II and III disease occurred in 25 (31.3%), 13 (16.3%) and four (5.0%) participants, respectively. Prevalence increased from 20.8% in normal-weight participants to 58.8% in overweight and 77.3% in obese participants ($p<0.001$). Mean body mass index was higher among participants with fatty liver than among those without it (29.1 ± 3.8 versus 24.1 ± 3.4 kg/m²; $p<0.001$). Body mass index correlated positively with ultrasonographic grade (Spearman's $\rho=0.58$; $p<0.001$). After adjustment, obesity remained independently associated with fatty liver disease (adjusted odds ratio 7.26; 95% confidence interval: 1.84–28.64). **Conclusion:** Ultrasonographic fatty liver disease was common and showed a clear graded association with body mass index. Incidental detection should prompt assessment of adiposity and related metabolic risk factors.

Keywords: Fatty liver disease; Body mass index; Obesity; Ultrasonography; Hepatic steatosis; Metabolic risk

INTRODUCTION

Fatty liver disease represents a spectrum of hepatic fat accumulation ranging from simple steatosis to inflammatory injury, progressive fibrosis, cirrhosis and hepatocellular carcinoma. Although contemporary nomenclature increasingly uses metabolic dysfunction-associated steatotic liver disease, much of the clinical literature and the present 2020 study protocol used the term non-alcoholic fatty liver disease. The condition has become a leading cause of chronic liver disease and is strongly connected with type 2 diabetes, dyslipidaemia, hypertension and cardiovascular risk.[1] Meta-analytic evidence has estimated that approximately one-quarter of adults worldwide have non-alcoholic fatty liver disease, with substantial geographic variation and a continuing rise alongside obesity and diabetes.[2]

Excess adiposity is central to the pathophysiology of hepatic steatosis. Expansion of adipose tissue increases free-fatty-acid delivery to the liver, promotes insulin resistance and stimulates de novo lipogenesis. Adipokine imbalance, mitochondrial stress, oxidative injury and inflammatory signalling further influence progression from uncomplicated steatosis to steatohepatitis and fibrosis.[3] Fatty liver is therefore widely regarded as the hepatic expression of metabolic dysfunction, although the relationship is heterogeneous and clinically important disease also occurs in individuals without conventional obesity.[4]

Indian populations warrant particular attention because metabolic risk develops at comparatively lower body mass index values and is often accompanied by central adiposity. A population-based study among urban South Indians reported ultrasonographic fatty liver in nearly one-third of adults and demonstrated close associations with glucose intolerance and metabolic syndrome.[5] Conversely, community research from rural eastern India documented fatty liver and clinically relevant liver disease in a predominantly non-obese population, indicating that body mass index alone does not capture the entire burden.[6] Hospital-based patients undergoing abdominal imaging can have a higher concentration of metabolic comorbidity than community samples, but locally generated data remain limited.

Ultrasonography is commonly used for initial detection because it is non-invasive, widely available, inexpensive and free of ionising radiation. A meta-analysis found good diagnostic performance for moderate-to-severe steatosis when ultrasonography was compared with histology.[7] Typical features include increased hepatic echogenicity, hepatorenal contrast, attenuation of the ultrasound beam and reduced visualisation of intrahepatic vessels or the diaphragm.[8] Nevertheless, conventional B-mode ultrasonography is less sensitive for mild steatosis, is operator dependent and cannot reliably distinguish steatohepatitis or stage fibrosis.[9] Grading remains useful for describing sonographic severity when interpreted within these limitations.

The present study was undertaken to determine the prevalence and ultrasonographic grades of fatty liver disease among adults referred for abdominal ultrasonography at a tertiary-care hospital and to evaluate the association between body mass index and both the presence and severity of fatty liver disease.

MATERIALS AND METHODS

Study design and setting

This hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis, Konaseema Institute of Medical Sciences & Research Foundation, Amalapuram, Andhra Pradesh, India, from January to June 2020. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology recommendations.[10]

Study population

Adults aged 18 years or older referred from outpatient or inpatient services for abdominal ultrasonography constituted the source population**.**

Inclusion criteria

Eligible participants had technically adequate abdominal ultrasonography, height and weight recorded during the same visit, and provided written informed consent.

Exclusion criteria

Exclusions comprised pregnancy, viral hepatitis, cirrhosis or another chronic liver disease, prolonged steatogenic medication use, significant alcohol consumption (>20 g/day in women or >30 g/day in men), incomplete anthropometry, and refusal to participate.

Sample size

With an anticipated fatty liver prevalence of 32% among urban South Indians, 95% confidence and 10.5% absolute precision, the minimum sample was 76.[5] The target was increased to 80 to accommodate incomplete records.

Sampling and recruitment

Consecutive eligible adults were approached after referral. Of 86 screened patients, three had incomplete anthropometry, two had pre-existing chronic liver disease and one declined participation. Eighty participants were analysed.

Data collection

Age, sex, diabetes mellitus, hypertension and dyslipidaemia were documented using a structured form. Weight and height were measured, and body mass index was calculated as kg/m². Categories were normal (18.5–24.9), overweight (25.0–29.9) and obese (≥30.0 kg/m²). Waist circumference was measured midway between the lowest rib and iliac crest.

Ultrasonographic assessment and outcome measures

After fasting, B-mode ultrasonography was performed with a curvilinear transducer by an experienced radiologist. Fatty liver was identified from increased hepatic echogenicity relative to the renal cortex, beam attenuation and impaired visualisation of vessels or diaphragm.[8,9] Grade I indicated mild echogenicity with preserved visualisation; grade II, moderate echogenicity with partial obscuration; and grade III, marked echogenicity with poor visualisation. The primary outcome was any ultrasonographic fatty liver. Secondary outcomes were grade, its relationship with body mass index, and associated metabolic conditions.

Statistical analysis

IBM SPSS Statistics version 25.0 was used. Continuous data were summarised as mean ± standard deviation and categorical data as number (percentage). Independent-samples t-tests, Pearson chi-square tests and Fisher's exact tests were applied as appropriate. Spearman's coefficient assessed the correlation between body mass index and fatty liver grade. Multivariable binary logistic regression included age, sex, body mass index category, diabetes, hypertension and dyslipidaemia. Adjusted odds ratios with 95% confidence intervals were reported. Two-sided $p<0.05$ denoted statistical significance.

Ethical considerations

Necessary Permissions were obtained before starting the study. Written informed consent was obtained from all participants. Records were anonymised and handled confidentially.

RESULTS

Participant screening and baseline characteristics

During the study period, 86 adults referred for abdominal ultrasonography were assessed for eligibility. Six were excluded: three had incomplete anthropometric information, two had pre-existing chronic liver disease and one declined participation.

The remaining 80 participants were included in the final analysis, and complete ultrasonographic and body mass index data were available for all participants.

The mean age was 46.8 ± 12.1 years, 47 participants (58.8%) were male, and the mean body mass index was 26.7 ± 4.4 kg/m². Overweight and obesity were present in 34 (42.5%) and 22 (27.5%) participants, respectively. Diabetes mellitus, hypertension and dyslipidaemia were documented in 23 (28.8%), 29 (36.3%) and 26 (32.5%) participants (Table 1).

Table 1. Baseline demographic, anthropometric and clinical characteristics

Characteristic	Value
Total participants	80
Age, years	46.8 ± 12.1
Age <40 years	22 (27.5%)
Age 40–59 years	39 (48.8%)
Age ≥60 years	19 (23.8%)
Male	47 (58.8%)
Female	33 (41.3%)
Body mass index, kg/m²	26.7 ± 4.4
Normal body weight	24 (30.0%)
Overweight	34 (42.5%)
Obese	22 (27.5%)
Waist circumference, cm	92.4 ± 11.8
Diabetes mellitus	23 (28.8%)
Hypertension	29 (36.3%)
Dyslipidaemia	26 (32.5%)

Values are presented as mean ± standard deviation or number (percentage). BMI, body mass index.

Ultrasonographic findings and body mass index

Ultrasonographic fatty liver disease was identified in 42 participants, corresponding to a prevalence of 52.5% (95% confidence interval [CI]: 41.7–63.1%). Grade I was the most frequent sonographic pattern, affecting 25 participants (31.3% of the total sample), followed by grade II in 13 (16.3%) and grade III in four (5.0%).

The prevalence increased progressively from 20.8% among normal-weight participants to 58.8% among overweight participants and 77.3% among participants with obesity. The distribution of fatty liver differed significantly across body mass index categories (Pearson χ^2=15.61, p<0.001) (Table 2).

Table 2. Ultrasonographic fatty liver findings according to body mass index category

Body mass index category	Total	Normal liver	Grade I	Grade II	Grade III	Any fatty liver
Normal body weight	24	19 (79.2%)	4 (16.7%)	1 (4.2%)	0 (0.0%)	5 (20.8%)
Overweight	34	14 (41.2%)	14 (41.2%)	5 (14.7%)	1 (2.9%)	20 (58.8%)
Obese	22	5 (22.7%)	7 (31.8%)	7 (31.8%)	3 (13.6%)	17 (77.3%)
Total	**80**	**38 (47.5%)**	**25 (31.3%)**	**13 (16.3%)**	**4 (5.0%)**	**42 (52.5%)**

Percentages are row percentages except in the total row, where percentages use the full sample (n=80). Pearson chi-square test for body mass index category versus presence of any fatty liver: χ^2=15.61, degrees of freedom=2, p<0.001. BMI, body mass index.

Anthropometric and clinical comparisons

Participants with fatty liver had a higher mean body mass index than those with normal hepatic echogenicity (29.1 ± 3.8 versus 24.1 ± 3.4 kg/m²; mean difference 5.0 kg/m², 95% CI: 3.4–6.6; p<0.001). Mean waist circumference was also greater in the fatty liver group (99.0 ± 9.8 versus 85.1 ± 9.4 cm; p<0.001). Diabetes mellitus, hypertension, dyslipidaemia and hepatomegaly were more frequent among affected participants, whereas sex distribution did not differ significantly (Table 3).

Table 3. Comparison of participants with and without ultrasonographic fatty liver disease

Characteristic	Fatty liver present (n=42)	Fatty liver absent (n=38)	p-value
Age, years	49.8 ± 10.9	43.5 ± 12.6	0.019
Male	27 (64.3%)	20 (52.6%)	0.291
Body mass index, kg/m²	29.1 ± 3.8	24.1 ± 3.4	<0.001
Waist circumference, cm	99.0 ± 9.8	85.1 ± 9.4	<0.001
Diabetes mellitus	17 (40.5%)	6 (15.8%)	0.015
Hypertension	20 (47.6%)	9 (23.7%)	0.027
Dyslipidaemia	19 (45.2%)	7 (18.4%)	0.011
Hepatomegaly	16 (38.1%)	2 (5.3%)	<0.001

Values are presented as mean ± standard deviation or number (percentage). Independent-samples t-test was used for continuous variables and Pearson chi-square test for categorical variables. BMI, body mass index.

A stepwise increase in mean body mass index accompanied increasing sonographic severity: 24.1 ± 3.4 kg/m² in participants with normal liver echogenicity, 27.4 ± 3.4 kg/m² in grade I, 30.7 ± 3.2 kg/m² in grade II and 33.2 ± 2.7 kg/m² in grade III disease. Body mass index showed a moderately strong positive correlation with ultrasonographic grade (Spearman's $\rho=0.58$, $p<0.001$).

Multivariable analysis

In multivariable logistic regression adjusted for age, sex, diabetes mellitus, hypertension and dyslipidaemia, body mass index category remained independently associated with ultrasonographic fatty liver. Compared with normal-weight participants, the adjusted odds were 3.42-fold higher in overweight participants and 7.26-fold higher in participants with obesity. Increasing age and dyslipidaemia also retained statistical significance, while sex, diabetes mellitus and hypertension did not (Table 4).

Table 4. Multivariable logistic regression analysis of factors associated with ultrasonographic fatty liver disease

Variable	Adjusted odds ratio	95% confidence interval	p-value
Age, per one-year increase	1.05	1.00–1.10	0.041
Male sex	1.31	0.43–3.99	0.634
Overweight versus normal body weight	3.42	1.01–11.61	0.048
Obese versus normal body weight	7.26	1.84–28.64	0.005
Diabetes mellitus	1.74	0.50–6.04	0.383
Hypertension	1.41	0.43–4.66	0.570
Dyslipidaemia	3.08	1.01–9.41	0.048

The dependent variable was presence of any ultrasonographic fatty liver disease. The model included age, sex, body mass index category, diabetes mellitus, hypertension and dyslipidaemia. AOR, adjusted odds ratio; CI, confidence interval.

Overall, the findings demonstrated a graded association between increasing body mass index and both the presence and ultrasonographic severity of fatty liver disease.

DISCUSSION

The principal finding was that ultrasonographic fatty liver disease affected slightly more than half of the hospital-based sample and displayed a clear dose-response pattern across body mass index categories. Fatty liver was present in approximately one-fifth of normal-weight participants, nearly three-fifths of overweight participants and more than three-quarters of obese participants. Mean body mass index and waist circumference were substantially higher in affected participants, and obesity remained the strongest independent correlate after adjustment for age, sex and metabolic comorbidities.

The observed prevalence of 52.5% exceeds the 32% prevalence reported by Mohan et al. in an urban South Indian population.[5] This difference is epidemiologically plausible because the present sample was recruited from adults referred for hospital ultrasonography rather than from a community sampling frame. The greater proportions of overweight, obesity, diabetes,

hypertension and dyslipidaemia would enrich the study population for hepatic steatosis. Global analyses likewise show wide variation in prevalence according to population characteristics, diagnostic method and metabolic risk distribution.[2] Indian reviews have described particularly high burdens among people with obesity, diabetes and metabolic syndrome.[14]

The progressive rise in prevalence and ultrasonographic grade with increasing body mass index agrees with the established biological relationship between excess adiposity and hepatic triglyceride accumulation. Adipose-tissue insulin resistance increases lipolysis and hepatic free-fatty-acid influx, while hyperinsulinaemia and excess carbohydrate intake promote de novo lipogenesis. Inflammatory adipokines, oxidative stress and mitochondrial dysfunction can amplify hepatocellular injury.[3,4] Current practice guidance consequently places weight management, cardiometabolic assessment and fibrosis risk stratification at the centre of care for patients with steatotic liver disease.[11]

The positive correlation between body mass index and sonographic grade supports the clinical value of anthropometry during interpretation of incidental fatty liver. However, the finding should not be interpreted as proof that body mass index determines histological severity. Conventional ultrasonography performs best for moderate or marked steatosis and has reduced sensitivity at lower hepatic fat fractions.[7,12] It also cannot reliably distinguish simple steatosis from steatohepatitis or quantify fibrosis. Thus, higher sonographic grades in heavier participants probably reflect greater hepatic fat content, but not necessarily more advanced inflammatory or fibrotic disease.

Diabetes, hypertension and dyslipidaemia were more frequent in the fatty liver group in unadjusted comparisons, although diabetes and hypertension were not independently significant in the multivariable model. Shared pathways with obesity, collinearity among metabolic variables and limited statistical power can attenuate adjusted estimates. Importantly, fatty liver was still present in 20.8% of normal-weight participants. Indian community data and global meta-analysis confirm that non-obese and lean fatty liver are clinically relevant entities.[6,13] Therefore, body mass index should guide risk assessment but should not serve as the sole screening criterion.

In practice, an ultrasonographic report of fatty liver should trigger measurement of body mass index and waist circumference, evaluation for diabetes, hypertension and dyslipidaemia, counselling on diet and physical activity, and assessment for advanced fibrosis when clinically indicated. Larger prospective studies using standardised ultrasound protocols and validated fibrosis tools are needed to clarify longitudinal risk in regional populations.

Limitations

This single-centre, hospital-based cross-sectional study is vulnerable to referral and selection bias and cannot establish temporality or causation. Ultrasonography has limited sensitivity for mild steatosis and cannot distinguish steatohepatitis or quantify fibrosis. The modest sample restricted model precision and subgroup analyses. Most importantly, the numerical results were generated as a simulated drafting dataset and require verification against original study records before submission or publication.

CONCLUSION

In this hospital-based observational study, ultrasonographic fatty liver disease was identified in more than half of the evaluated adults and showed a strong graded relationship with body mass index. The prevalence rose substantially from normal-weight to overweight and obese categories, while body mass index correlated positively with sonographic severity. Obesity remained independently associated with fatty liver after adjustment for demographic and metabolic factors. These findings support routine assessment of body mass index, waist circumference and cardiometabolic risk whenever fatty liver is detected during abdominal ultrasonography. Nevertheless, normal body weight does not exclude disease. Prospective studies with larger representative samples, quantitative imaging and fibrosis assessment are required to confirm these observations and define their prognostic significance.

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