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Prevalence and Risk Factors of Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD) in Lean Individuals: A Cross-Sectional Study

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ABSTRACT

Background: Metabolically Associated Steatotic Liver Disease (MASLD) shows a wide prevalence in India, ranging from 10% to 50%, predominantly in overweight or diabetic individuals. However, increasing evidence reveals MASLD in lean populations, particularly in Asia. This study aimed to evaluate the prevalence and associated risk factors of MASLD among lean individuals attending the Internal Medicine and Gastroenterology outpatient department at Amala Institute of Medical Sciences.

Methods: A hospital-based cross-sectional study was conducted from August 2023 to July 2024. Using purposive sampling, 250 adult patients with diagnosed fatty liver disease were enrolled. Patients with BMI<23 were classified as lean. Data on demographics, clinical parameters, and biochemical markers were collected. Statistical analysis involved Fisher's exact test, considering p<0.05 significant.

Results: The prevalence of MASLD in lean patients was found to be 17.2%. Female lean patients showed a higher risk (p=0.02, OR=0.08) of MASLD. Significant risk factors included diabetes mellitus (p=0.02, OR=3.81) and hypertension (p=0.01, OR=4.02). Altered bilirubin (p=0.004, OR=5.73), lipid profile abnormalities (p=0.001, OR=7.21), and elevated AST/ALT ratios (p=0.01, OR=4.12) were significantly associated with MASLD in the lean group.

Conclusion: MASLD affects a considerable proportion of lean individuals with BMI below 23. Female sex, diabetes, and hypertension are significant risk factors. Biochemical abnormalities in liver enzymes and lipids are more prevalent in MASLD patients within the lean subset.

Key-words: MASLD, MASH, Lean metabolic dysfunction, Diabetic Mellitus, Obesity

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INTRODUCTION

Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly referred to as non-alcoholic fatty liver disease (NAFLD), is now recognized as the most prevalent chronic liver disease globally, with a rapidly rising burden in developing nations, including India. The condition encompasses a spectrum of hepatic disorders ranging from simple steatosis to metabolic-associated steatohepatitis (MASH), progressive fibrosis, cirrhosis, and even hepatocellular carcinoma (HCC). Its increasing

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recognition as a major public health concern stems from its close association with components of the metabolic syndrome, particularly obesity, insulin resistance, type 2 diabetes mellitus (T2DM), dyslipidemia, and hypertension. [1-5]

Traditionally, MASLD has been viewed as a disease primarily affecting overweight or obese individuals, owing to the strong correlation between excess adiposity and hepatic lipid accumulation. However, an important and emerging phenotype, lean MASLD, is now garnering global attention. Lean MASLD refers to the presence of hepatic steatosis and associated metabolic dysfunction in individuals with a body mass index (BMI) below the traditional cut-off for overweight or obesity, typically <23 kg/m² in Asian populations. This phenotype challenges long-standing clinical assumptions and calls for a paradigm shift in diagnostic and screening strategies.[6-10]

South Asian populations, including Indians, exhibit a unique metabolic profile that predisposes them to insulin resistance and cardiovascular risk factors at lower levels of adiposity compared to Western populations. Several studies have demonstrated that lean Asian men may have three to four times higher insulin resistance than their Western counterparts, which may explain the disproportionately high rates of MASLD despite seemingly normal BMI. This “metabolically obese normal weight” (MONW) phenotype is characterized by visceral adiposity, ectopic fat deposition, and a pro-inflammatory state, all of which contribute to hepatic steatosis and disease progression.[11-14]

Given the growing burden of MASLD in India, particularly in urban centers and tertiary care institutions, it is imperative to better understand its presentation in lean individuals. Identifying the prevalence, metabolic profiles, and potential risk factors in this population could inform more inclusive screening strategies and tailored management protocols. Furthermore, such studies could provide insights into the underlying pathophysiological mechanisms that distinguish lean MASLD from its obese counterpart, paving the way for targeted therapeutic research.[15-18]

Despite growing awareness, literature on lean MASLD in the Indian context remains limited. There is a pressing need for region-specific data that accounts for the unique genetic, cultural, and dietary influences shaping disease patterns in South Asia. Understanding how lean MASLD manifests in Indian populations could bridge a significant gap in hepatology and metabolic research and help develop risk prediction models that go beyond BMI to include waist circumference, insulin resistance markers, and lipid abnormalities.

In this context, the present study aims to evaluate the prevalence and risk factors of MASLD in lean individuals attending a tertiary care medical college in Kerala, India. By focusing on a population that is often underrepresented in liver disease research, this study seeks to uncover critical insights that could reshape screening paradigms and improve outcomes for a high-risk yet overlooked group.[19-21]

MATERIALS AND METHODS

Study Design and Setting- This hospital-based cross-sectional study was conducted at the Department of Internal Medicine and Department of Gastroenterology, Amala Institute of Medical Sciences, Kerala, between August 2023 and July 2024. A total of 250 adult patients (≥18 years) with ultrasound-confirmed fatty liver disease within the past 12 months, attending the General Medicine and Gastroenterology outpatient departments, were enrolled using purposive sampling.

Inclusion Criteria- Patients aged ≥18 years with imaging-confirmed hepatic steatosis (ultrasound within the past 12 months), BMI <23 kg/m², and at least one of the following metabolic risk factors were included:

- ✓ Type 2 diabetes mellitus
- ✓ Dyslipidemia (triglycerides >150 mg/dL or HDL <40 mg/dL in men / <50 mg/dL in women)
- ✓ Hypertension (≥130/85 mmHg or on treatment)
- ✓ Impaired fasting glucose or insulin resistance

Exclusion Criteria:

- ✓ Significant alcohol intake (>30 g/day for men or >20 g/day for women)
- ✓ Viral hepatitis (HBsAg or anti-HCV positive)
- ✓ Drug-induced steatosis (e.g., due to corticosteroids, tamoxifen, methotrexate, amiodarone)
- ✓ Other chronic liver diseases (autoimmune hepatitis, Wilson’s disease, hemochromatosis, PBC/PSC)
- ✓ History of malignancy, pregnancy, or incomplete data

Data collection and variables- Data were collected using a structured case pro forma and included:

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- Demographics (age, sex)
- Clinical parameters (BP, diabetes status, medication history)
- Anthropometrics (weight, height, BMI, waist circumference)

Laboratory investigations included fasting blood sugar, liver function tests (AST, ALT, total bilirubin), and lipid profile parameters (triglycerides, HDL, LDL). The diagnosis of fatty liver was established based on abdominal ultrasonography findings retrieved from hospital records.

Operational definitions:

Lean MASLD- BMI <23 kg/m² with hepatic steatosis and ≥1 metabolic risk factor

Abnormal lipid profile- TG >150 mg/dL and/or HDL below gender-specific cut-offs

Elevated AST/ALT ratio- AST/ALT ≥1

Statistical Analysis- Data analysis was done using GraphPad INSTAT software. Descriptive statistics were expressed as means, standard deviations, frequencies, and percentages. Associations between categorical variables were analyzed using Fisher's exact test. A $p<0.05$ was considered statistically significant. Odds ratios (OR) with 95% confidence intervals (CI) were calculated for significant associations.

Ethical Clearance- Ethical clearance was obtained from the Institutional Ethics Committee of Amala Institute of Medical Sciences.

RESULTS

Among the 250 patients with ultrasound-confirmed fatty liver disease, 43 individuals (17.2%) were classified as lean, having a BMI less than 23 kg/m² (Table 1).

Table 1: Prevalence of MASLD in Lean Patients

Total fatty liver patients	250
Lean fatty liver patients (BMI <23)	43 (17.2%)

Within this lean subset, female patients exhibited a significantly higher risk of MASLD despite their smaller proportion overall, suggesting a gender-specific susceptibility in lean individuals (p= 0.02, OR= 0.08) (Table 2).

Table 2: Gender Distribution among Lean MASLD Patients

Gender	**MASLD Lean Patients (n=43)**	**Non-MASLD Lean Patients (n=207)**
Male	36 (83.7%)	178 (86.0%)
Female	7 (16.3%)	29 (14.0%)
p-value	0.02	-
Odds Ratio (OR)	0.08	-

Further analysis revealed that metabolic comorbidities such as hypertension and type 2 diabetes mellitus were strongly associated with MASLD among lean individuals. Hypertension was present in 80.5% of lean MASLD cases compared to 33% in their non-MASLD counterparts (p= 0.01, OR= 4.02). In comparison, diabetes mellitus was observed in 78.9% of MASLD patients versus 40.2% in non-MASLD lean individuals (p=0.02, OR=3.81) (Table 3).

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Table 3: Risk Factors Associated with MASLD in Lean Patients

Risk Factor	MASLD Lean Patients	Non-MASLD Lean Patients	p-value	Odds Ratio (OR)
Hypertension	35 (80.5%)	68 (33%)	0.01	4.02
Diabetes Mellitus	34 (78.9%)	83 (40.2%)	0.02	3.81

Biochemical parameters also showed notable differences. Altered bilirubin levels (84.0% vs. 38.5%, p= 0.004, OR= 5.73), abnormal lipid profiles (86.0% vs. 31.4%, p= 0.001, OR= 7.21), and elevated AST/ALT ratios (79.1% vs. 21.7%, p= 0.01, OR= 4.12) were significantly more prevalent in lean MASLD patients, suggesting ongoing hepatocellular injury and underlying metabolic dysregulation (Table 4).

Table 4: Biochemical Abnormalities in Lean MASLD Patients

Parameter	MASLD Lean Patients	Non-MASLD Lean Patients	p-value	Odds Ratio (OR)
Altered Bilirubin	36 (84%)	80 (38.5%)	0.004	5.73
Altered Lipid Profile	37 (86%)	65 (31.4%)	0.001	7.21
Elevated AST/ALT	34 (79.1%)	45 (21.7%)	0.01	4.12

Fig. 1 depicts the proportion of MASLD among lean and non-lean individuals, highlighting that a notable percentage of lean patients also meet MASLD criteria despite a normal BMI.

Fig. 2 presents the prevalence of major metabolic risk factors—including diabetes, hypertension, and dyslipidemia—within the lean subgroup, indicating that significant metabolic dysfunction is present even among individuals who are not overweight. Together, these visuals emphasize the silent burden of lean MASLD and reinforce the need for metabolic screening beyond BMI-based assessments.

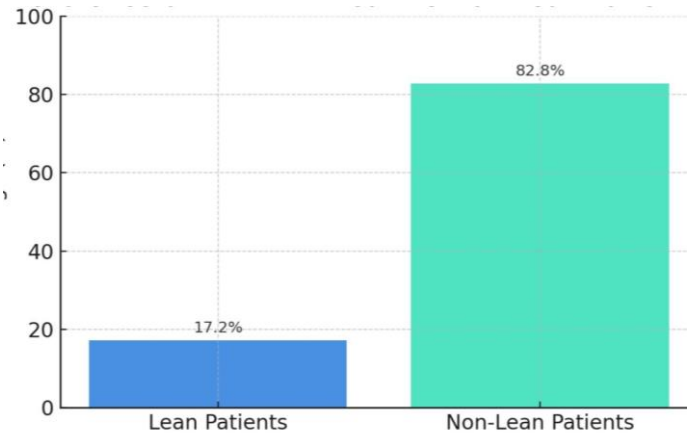

Fig. 1: Prevalence of MASLD in Lean vs Non-Lean Patients (%)

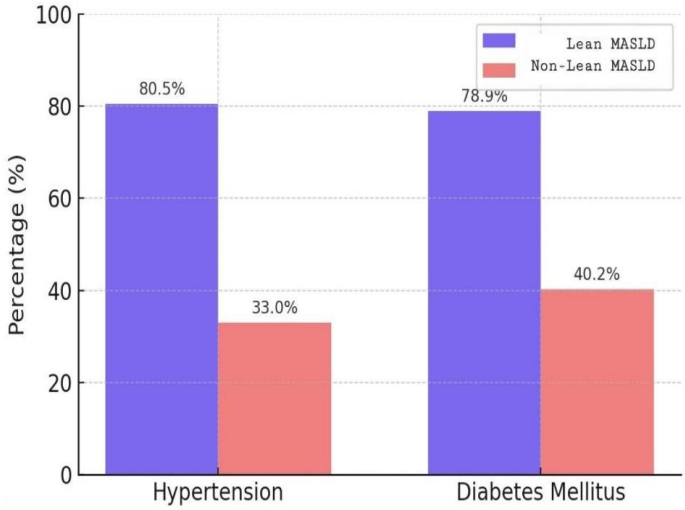

Fig. 2: Prevalence of Risk Factors in Lean Patients (%)

DISCUSSION

This hospital-based cross-sectional study identified a 17.5% prevalence of MASLD among lean individuals, a figure that lies within the reported range of 5% to 34% documented in both Indian and broader Asian studies. This reinforces the growing body of evidence that MASLD is not solely a disease of the overweight or obese but also affects individuals with normal or low BMI, a phenotype often under-recognized in routine clinical practice. The findings highlight that lean MASLD is not a

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rarity but a clinically significant subset of the MASLD spectrum with unique risk factors and metabolic profiles.

One of the most striking observations from this study was the higher prevalence of MASLD among lean females, which contrasts with many Western cohorts that typically report a male predominance in MASLD cases. This gender variation could be attributed to multiple factors, including hormonal influences (e.g., estrogen's role in lipid metabolism), sociocultural dietary patterns, and physical activity levels prevalent in Indian women. Additionally, genetic predisposition and environmental stressors specific to South Asian populations may contribute to differential disease expression between genders. This warrants further investigation through population-specific genetic and lifestyle studies to clarify these patterns.

Consistent with existing literature, our study identified type 2 diabetes mellitus and hypertension as strong independent risk factors for MASLD, even in the absence of obesity. These associations reinforce the understanding that MASLD is primarily driven by metabolic dysfunction rather than adiposity alone. Insulin resistance, a central component of metabolic syndrome, promotes hepatic lipid accumulation, oxidative stress, and inflammation, key mechanisms in MASLD pathogenesis. In lean individuals, this may be further compounded by ectopic fat deposition, sarcopenia, and a higher visceral fat-to-subcutaneous fat ratio, particularly common in South Asians. This metabolic vulnerability may explain why individuals with a normal BMI are still at high risk for developing MASLD and progressing to more severe liver disease.[22-28]

In terms of biochemical abnormalities, elevated AST/ALT ratios, altered bilirubin levels, and dyslipidemia were significantly associated with MASLD among lean individuals in our cohort. These findings are indicative of ongoing hepatocellular injury and metabolic derangement. Elevated transaminase levels, while not always present in MASLD, are useful markers when interpreted alongside imaging and metabolic risk factors. The presence of dyslipidemia, particularly hypertriglyceridemia and low HDL, aligns with the known lipid metabolism disturbances in MASLD. These laboratory parameters are especially valuable in resource-limited settings, where access to advanced imaging or liver biopsy may be limited.

The results of this study are also consistent with several systematic reviews and prospective cohort studies that underscore the role of insulin resistance, glucose intolerance, and dyslipidemia in the development and progression of MASLD regardless of BMI. Studies in Asian populations have demonstrated that "metabolically obese normal weight" (MONW) individuals exhibit similar or even higher risks for cardiovascular and hepatic complications compared to their obese counterparts. The findings of our study further support the inclusion of lean individuals with metabolic risk factors in MASLD screening programs.

Importantly, the clinical implications of this study are significant. The conventional reliance on BMI as a proxy for metabolic risk is no longer adequate. Our data strongly suggest that clinicians must maintain a high index of suspicion for MASLD in lean individuals, especially those with diabetes, hypertension, or abnormal liver enzymes. Relying solely on obesity as a criterion for MASLD screening risks missing a substantial proportion of affected individuals, particularly in South Asia where visceral adiposity and insulin resistance are common even in individuals with normal BMI.[29-34]

This necessitates the development of tailored screening algorithms that incorporate metabolic markers, waist circumference, and possibly genetic predisposition to better capture at-risk individuals. For example, routine liver function tests and ultrasonography should be considered in lean diabetic or hypertensive patients, regardless of BMI. Furthermore, public health policies must broaden their focus from obesity alone to the entire spectrum of metabolic risk, especially in high-burden regions like India.

This study contributes to the growing recognition of lean MASLD as a distinct and clinically relevant phenotype in the Indian population. It underscores the need for heightened clinical awareness, especially in lean individuals with metabolic abnormalities, and supports a move towards inclusive and metabolically focused screening strategies. Future research should focus on prospective, community-based cohorts and incorporate genetic, dietary, and lifestyle data to further elucidate the pathophysiology and outcomes of lean MASLD. Addressing this silent epidemic is vital to prevent the progression of liver disease and associated systemic complications in this overlooked population.[35-40]

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LIMITATIONS

Despite its valuable insights, this study is not without limitations. Firstly, as a hospital-based study, there is potential for selection bias, as the sample may not fully represent the general community. Patients attending tertiary care centers may have more advanced disease or associated comorbidities. Secondly, the cross-sectional design limits the ability to establish temporal or causal relationships between risk factors and MASLD development. Longitudinal follow-up studies would be needed to assess the progression of lean MASLD and identify predictors of disease advancement. Thirdly, although imaging (typically ultrasound) was used for diagnosis, it lacks sensitivity in early or mild steatosis and cannot differentiate between simple steatosis and MASH.

CONCLUSIONS

This study highlights that MASLD is not confined to obese individuals but significantly affects lean adults as well, with a prevalence of 17.2% in the studied population. Female gender, diabetes, and hypertension emerged as key risk factors. Routine metabolic evaluation, including liver function and lipid profiling, is essential in lean individuals to enable early detection and intervention. A shift in screening practices is needed to include metabolically at-risk individuals regardless of BMI.

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