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Research

Age and Gender Related Differences in Non Alcoholic Fatty Liver Disease Risk: Role of Cardio metabolic Factors, Obesity and Menopausal Status in an Indian Tertiary Care Population

Akhila Ajith[1*], Nuvvula Sreya[2], Sai Somanath Madupathi[3], Rabia Khatoon Farah[4], Dr. T. Praveen Kumar[5], Dr. M. Satya Pratik[6]

[1, 2, 3, 4]Pharm D, Department of Pharmacy Practice, Malla Reddy College of Pharmacy, Hyderabad, Telangana, India

[5]Professor, Department of Pharmacy Practice, Malla Reddy College of Pharmacy, Hyderabad, Telangana, India

[6]Assistant Professor, Department of General Medicine, MRIMS, Suraram, Hyderabad, Telangana, India.

*Author for Correspondence**:** Akhila Ajith

Email: akhilaajith1310@gmail.com

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Abstract

Background: Non-alcoholic fatty liver disease (NAFLD) is a leading cause of chronic liver disease worldwide and is closely linked to obesity, metabolic syndrome and insulin resistance. Emerging evidence suggests that age, gender and hormonal transitions; particularly menopause may significantly influence NAFLD risk and progression, yet data from Indian populations have remain limited.

Objective: To evaluate age and gender related differences in NAFLD risk and to assess the influence of cardio metabolic risk factors, obesity and menopausal status using the Fatty Liver Index (FLI).

Methods: A prospective observational study was conducted among 150 adults aged ≥31 years attending a tertiary care hospital in India. Demographic characteristics, lifestyle factors, comorbidities, anthropometric measurements and biochemical parameters were collected. NAFLD risk was assessed using the Fatty Liver Index. Associations were evaluated using chi-square tests and correlation analysis. Multiple linear regressions were performed to identify predictors of FLI and logistic regression was used to determine factors associated with high risk NAFLD. Statistical significance was set at $p< 0.05$.

Results: Based on FLI, 14.7% of participants were classified as high risk for NAFLD (FLI > 60), while 84.7% were in the intermediate risk category. Females exhibited higher mean FLI values than males, with postmenopausal women demonstrating significantly elevated FLI scores compared to pre menopausal women. Obesity (BMI > 25 kg/m²), elevated triglyceride levels, sedentary lifestyle and metabolic syndrome were significantly associated with increased NAFLD risk. Post menopausal status emerged as an independent

predictor of high-risk NAFLD, with an adjusted odds ratio of 3.37. In multiple linear regression analysis, BMI, triglycerides and menopausal status were significant predictors of FLI ($R^2 = 0.884$, $p< 0.001$).
Conclusion: NAFLD risk is highly prevalent among middle-aged adults, particularly in females and postmenopausal women. Cardio metabolic risk factors, obesity and hormonal transitions play a crucial role in NAFLD development. Early identification and targeted lifestyle interventions focusing on weight management and metabolic control are essential to reduce NAFLD burden in high risk populations.

Keywords: Non-alcoholic fatty liver disease; Fatty Liver Index; Cardio metabolic risk factors; Obesity; Menopause; Metabolic syndrome.

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) has emerged as the most common chronic liver disorder worldwide, affecting approximately 25–30% of the adult population and representing a major public health challenge [1,2]. NAFLD is defined by excessive hepatic fat accumulation (>5% of hepatocytes) in the absence of significant alcohol consumption or other secondary causes of steatosis [3].

The disease encompasses a wide pathological spectrum ranging from simple steatosis (non-alcoholic fatty liver, NAFL) to non-alcoholic steatohepatitis (NASH), progressive fibrosis, cirrhosis, and hepatocellular carcinoma (HCC) [4]. Although only a minority of patient's progress to advanced liver disease, NAFLD is strongly associated with increased cardiovascular morbidity and mortality, which constitutes the leading cause of death in this population [5].

The global rise in NAFLD prevalence closely parallels the increasing burden of obesity, Type 2 Diabetes Mellitus (T2DM), Dyslipidaemia, Hypertension and Metabolic syndrome. NAFLD is now widely recognized as the hepatic manifestation of metabolic syndrome and is characterized by insulin resistance, chronic low-grade inflammation, oxidative stress and altered lipid metabolism [6]. In India and other Asian countries, NAFLD prevalence is rising rapidly due to urbanization, sedentary lifestyles and dietary transitions, with recent studies reporting prevalence rates approaching 35–40% in adults [7,8]. The South Asian populations demonstrates a unique metabolic phenotype, with higher visceral adiposity and metabolic risk at lower body mass index (BMI), predisposing them to NAFLD even in the absence of overt obesity [9].

Age and sex are important modifiers of NAFLD risk, disease phenotype and progression. Epidemiological studies consistently report a higher prevalence of NAFLD in men during early and middle adulthood, whereas prevalence in women increases markedly after menopause [10]. This gender specific pattern is largely attributed to hormonal differences, particularly the protective role of estrogen. Estrogen enhances hepatic insulin sensitivity, suppresses de novo lipogenesis, promotes fatty acid oxidation and favors subcutaneous rather than visceral fat distribution [11]. Experimental and clinical evidence suggests that estrogen also exerts anti-inflammatory and anti-fibrotic effects by modulating hepatic stellate cell activation and inflammatory cytokine signaling [12]. Consequently, premenopausal women exhibit a lower risk of NAFLD and slower disease progression compared to age matched men.

The menopausal transition represents a critical biological event that substantially alters NAFLD risk in women. Declining estrogen levels during peri and post menopause are associated with increased visceral adiposity, insulin resistance, dyslipidaemia and systemic inflammation, all of which promote hepatic fat accumulation and fibrosis [13,14]. Large population based studies have demonstrated that postmenopausal women have a significantly higher prevalence of NAFLD and an increased risk of advanced fibrosis compared to premenopausal women, independent of age and BMI [15]. Furthermore, women with premature menopause or surgical oophorectomy appear to be at particularly high risk, suggesting a cumulative effect of estrogen deprivation on liver health [16].

Advancing age itself is an independent risk factor for NAFLD severity. While hepatic steatosis may decline in older adults, the prevalence of advanced fibrosis and cirrhosis increases, reflecting longer disease duration and cumulative metabolic injury [17]. Older individuals often present with relatively normal liver enzyme levels despite significant histological disease, complicating early detection [18]. These age-related differences underscore the need for reliable non-invasive tools to identify individuals at high risk for NAFLD and its complications across different demographic groups.

Liver biopsy remains the gold standard for diagnosing and staging NAFLD; however, its invasiveness, cost, sampling variability, and limited feasibility in large populations restrict its routine use [19]. Consequently, non-invasive diagnostic tools have gained increasing importance. The Fatty Liver Index (FLI) is a validated, simple and cost-effective scoring system based on BMI, waist circumference, triglycerides and gamma-glutamyl transferase levels [20]. FLI has demonstrated good diagnostic accuracy for hepatic steatosis in both clinical and population-based studies and is particularly useful for large-scale screening and risk stratification where imaging or biopsy is impractical [21].

Despite extensive global research, data examining the combined influence of age, gender, menopausal status and cardio metabolic risk factors on NAFLD in Indian populations remain limited. Given the high prevalence of metabolic syndrome and the unique metabolic risk profile of South Asians, region-specific evidence is essential to inform targeted screening and preventive strategies. Understanding how hormonal transitions and cardio metabolic factors interact to influence NAFLD risk may help identify vulnerable subgroups that would benefit from early intervention.

Therefore, this study aimed to evaluate age and gender related differences in NAFLD risk using the Fatty Liver Index in an Indian hospital based population. Additionally, the study sought to assess the influence of cardio metabolic risk factors, obesity and menopausal status on NAFLD risk and to identify independent predictors associated with elevated FLI scores.

METHODS

A prospective observational study was conducted at a tertiary care teaching hospital in Telangana, India, over a period of six months. The study was initiated after obtaining approval from the Institutional Ethics Committee, and all procedures were performed in accordance with the ethical standards of the institutional research committee and the principles outlined in the Declaration of Helsinki.

A total of 150 adult participants aged 31 years and above were enrolled in the study. Participants attending the outpatient and inpatient departments during the study period were screened for eligibility. Individuals were included if they were willing to provide informed consent and had complete anthropometric and biochemical data required for the calculation of the Fatty Liver Index (FLI). Participants were excluded if they had a history of significant alcohol consumption, known chronic liver diseases (including viral hepatitis, autoimmune hepatitis or cirrhosis), drug-induced liver injury, pregnancy, severe systemic illness, or malignancy.

Demographic details such as age and gender were recorded using a structured data collection form. Clinical information included a documented history of Diabetes mellitus, Hypertension, Dyslipidaemia and Metabolic syndrome. Menopausal status among female participants was determined based on menstrual history and classified as premenopausal or postmenopausal.

Anthropometric measurements, including height, weight and waist circumference, were obtained using standardized measurement techniques. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Venous blood samples were collected from all participants after an overnight fast. Biochemical parameters analyzed included fasting blood glucose, serum triglycerides and gamma-glutamyl transferase (GGT). All laboratory investigations were performed in the hospital's central laboratory using standardized and validated analytical methods, with routine internal quality control measures in place.

The risk of non-alcoholic fatty liver disease was assessed using the Fatty Liver Index (FLI), a validated non-invasive scoring system derived from body mass index, waist circumference, serum triglyceride levels and GGT.

The Fatty Liver Index (FLI) was calculated using the following formula:

$$\text{Fatty liver index(FLI)} = \frac{e^{0.953}y}{(1+e^{0.953}y)} \times 100,$$

where $y = \ln(\text{TG}) + 0.139 \times \text{BMI} + 0.718 \times \ln(\text{GGT}) + 0.053 \times \text{WC} - 15.745$.

Here, TG is expressed as mg/dL; BMI is expressed as kg/m^2; GGT is expressed as U/L; and WC is measured in cm.

In this equation, triglycerides (TG) are expressed in mg/dL, body mass index (BMI) in kg/m², gamma-glutamyl transferase (GGT) in U/L, and waist circumference (WC) in centimeters.

Based on FLI values, all the participants were categorized into three groups: low risk (FLI < 30), intermediate risk (FLI 30–59) and high risk (FLI ≥ 60).

Data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Associations between categorical variables were analysed using the chi-square test. Correlation analysis was performed to evaluate relationships between FLI and cardio metabolic parameters.

Multiple linear regression analysis was used to identify independent predictors of FLI and logistic regression analysis was performed to determine factors associated with high-risk NAFLD (FLI ≥ 60). A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1. Baseline demographic and anthropometric characteristics (n = 150)

Variable	Overall
Age (years), mean ± SD	49.9 ± 7.8
Male, n (%)	81 (54.0)
Female, n (%)	69 (46.0)
BMI (kg/m²), mean ± SD	30.11 ± 2.16
Waist circumference (cm), mean ± SD	90.73 ± 4.72

Table 2. Lifestyle characteristics of participants

Variable	n (%)
Alcohol use (Yes)	9 (6.0)
Sedentary lifestyle	67 (44.7)
Moderate physical activity	80 (53.3)
Fast food ≥3 times/week	88 (58.6)

Table 3. Clinical comorbidities and metabolic syndrome

Condition	n (%)
Hypertension	35 (23.3)
Diabetes mellitus	12 (8.0)
Obesity	18 (12.0)
≥2 cardio metabolic conditions	61 (40.7)
Metabolic syndrome present	88 (58.7)

Table 4. Menopausal status and gender-wise metabolic differences

Variable	Male	Female	p-value
BMI (kg/m²)	29.90 ± 1.87	32.35 ± 2.45	0.04
Waist circumference (cm)	90.21 ± 3.93	93.35 ± 5.47	0.03
FLI	49.00 ± 12.95	62.20 ± 15.77	0.02
Post-menopausal (n, %)	—	55 (79.4)	—

Table 5. Prevalence of NAFLD based on Fatty Liver Index (FLI)

FLI category	n (%)
Low risk (<30)	1 (0.7)
Intermediate (30–60)	127 (84.7)
High risk (>60)	22 (14.7)

Table 6. FLI distribution by age group, gender, and menopausal status

Subgroup	High-risk FLI (%)
Age ≥60 years	21.3
Female	17.4
Male	12.3
Post-menopausal women	23.7
Pre-menopausal women	10.0

Table 7. Correlation between FLI and cardiometabolic parameters

Variable	r-value	p-value
BMI	0.795	<0.001
Triglycerides	0.575	<0.001
Age	0.236	0.009
HbA1c	0.312	0.045

Table 8. Multivariable regression analyses for NAFLD risk

A. Linear regression (FLI as outcome)

Predictor	β	p-value
BMI	4.34	<0.001
Triglycerides	0.34	<0.001
Female gender	6.63	0.006
Post-menopausal status	2.80	0.005

B. Logistic regression (High FLI >60

Predictor	Odds Ratio	p-value
BMI	21.9	0.023
Post-menopause	3.37	0.012
Triglycerides	1.27	0.009

A total of 150 participants were included in the study, comprising 81 males (54.0%) and 69 females (46.0%). The mean age of the study population was 49.9 ± 7.8 years. The majority of participants belonged to the 41–50-year age group (47.3%), followed by 51–60 years (24.0%), 31–40 years (16.7%), 61–70 years (9.3%), and ≥71 years (2.7%).

Based on body mass index classification, 54.0% of participants were overweight, 34.7% were obese, and 11.3% had normal BMI. Obesity was more prevalent among females (63.8%), whereas overweight status was more common among males (71.6%). The mean BMI of the study population was 30.11 ± 2.16 kg/m², and the mean waist circumference was 90.73 ± 4.72 cm.

Most participants (94.0%) reported no alcohol consumption. Physical activity assessment showed that 53.3% of participants had moderate activity levels, 44.7% were sedentary, and 2.0% were physically active. Fast-food consumption was reported as 3–4 times per week by 39.3% of participants, daily by 19.3%, once weekly by 28.7%, and rarely or never by 12.7%.

Hypertension was present in 23.3% of participants, diabetes mellitus in 8.0%, and obesity in 12.0%. Multiple cardio metabolic comorbidities were observed in 40.7% of participants. Metabolic syndrome was identified in 88 participants (58.7%), with a higher prevalence among males (61.7%) compared to females (55.1%). Among female participants, 55 (79.4%) were postmenopausal and 14 (20.6%) were premenopausal.

The mean fasting blood glucose level was 102.13 ± 21.43 mg/dL, triglycerides were 136.9 ± 13.8 mg/dL, HbA1c was 6.47 ± 1.56%, and gamma-glutamyl transferase was 14.55 ± 5.8 U/L. The overall mean Fatty Liver Index (FLI) was 50.6 ± 14.9. Based on FLI cut-offs, 84.7% of participants were classified as intermediate risk (FLI 30–60), 14.7% as high risk (FLI >60), and 0.7% as low risk (FLI <30).

High-risk FLI prevalence increased with age, from 8.7% in the 40–49-year group to 17.6% in the 50–59-year group and 21.3% among participants aged ≥60 years. High-risk FLI was observed in 17.4% of females and 12.3% of males. Among female participants, 23.7% of postmenopausal women had high-risk FLI compared to 10.0% of premenopausal women.

Chi-square analysis showed significant associations of metabolic syndrome with gender ($p = 0.034$), age group ($p = 0.031$), physical activity ($p = 0.008$), fast-food consumption ($p = 0.015$), stress ($p = 0.001$), menopausal status ($p = 0.0177$), patient history ($p = 0.025$), and sedentary lifestyle ($p = 0.018$). NAFLD presence (FLI ≥30) was significantly associated with gender ($p = 0.017$), age group ($p = 0.012$), menopausal status ($p = 0.018$), and obesity ($p = 0.008$).

Correlation analysis demonstrated a strong positive correlation between FLI and BMI ($r = 0.795$, $p < 0.001$) and triglycerides ($r = 0.575$, $p < 0.001$). Weak

but significant correlations were observed between FLI and age ($r = 0.236$, $p = 0.009$) and HbA1c ($r = 0.312$, $p = 0.045$).

Multiple linear regression analysis identified BMI ($\beta = 4.34$, $p < 0.001$), triglycerides ($\beta = 0.34$, $p < 0.001$), female gender ($\beta = 6.63$, $p = 0.006$), postmenopausal status ($\beta = 2.80$, $p = 0.005$), and age ($\beta = 0.17$, $p = 0.001$) as independent predictors of FLI ($R^2 = 0.884$). Logistic regression analysis showed that BMI (OR = 21.9, $p = 0.023$), postmenopausal status (OR = 3.37, $p = 0.012$), triglycerides (OR = 1.27, $p = 0.009$), fasting blood glucose (OR = 1.97, $p = 0.002$), age ($p = 0.009$), and gender ($p = 0.005$) were significant predictors of high NAFLD risk (FLI >60).

DISCUSSIONS

In this prospective observational study, a high burden of NAFLD risk was observed among middle-aged adults, with the majority of participants classified in the intermediate or high-risk categories based on the Fatty Liver Index. The study highlights significant associations between NAFLD risk and age, gender, obesity, cardio metabolic factors and menopausal status, underscoring the multifactorial nature of NAFLD in an Indian hospital-based population.

Age emerged as an important determinant of NAFLD risk in the present study. The prevalence of high-risk FLI increased progressively with advancing age, particularly among individuals aged 60 years and above. This finding is consistent with epidemiological evidence suggesting that cumulative metabolic exposure and prolonged insulin resistance contribute to progressive hepatic fat accumulation and fibrosis with increasing age. Although hepatic steatosis may plateau or decline in older individuals, the risk of advanced disease tends to increase, emphasizing the importance of age-specific screening strategies.

Gender-based differences in NAFLD risk were evident, with females demonstrating higher mean BMI, waist circumference, triglyceride levels and FLI values compared to males. While NAFLD has traditionally been reported as more prevalent in men, emerging evidence indicates that women, particularly after menopause may exhibit an increased metabolic and hepatic risk. The higher FLI observed among females in this study supports the growing recognition of sex-specific differences in NAFLD pathophysiology.

Menopausal status played a significant role in determining NAFLD risk among female participants. Postmenopausal women demonstrated a higher prevalence of high-risk FLI compared to premenopausal women, and menopausal status remained an independent predictor of FLI in both linear and logistic regression analyses. These findings align with existing literature suggesting that estrogen deficiency during the peri and post menopausal period leads to increased visceral adiposity, dyslipidaemia, insulin resistance and systemic inflammation, all of which contribute to hepatic steatosis and disease progression. The observed increase in BMI and triglyceride levels among postmenopausal women in this study further supports the biological plausibility of this association.

Obesity and adiposity were among the strongest predictors of NAFLD risk in the present study. BMI demonstrated a strong positive correlation with FLI and emerged as the most influential predictor in both linear and logistic regression models. This finding reinforces the central role of excess body weight in NAFLD development, particularly in South Asian populations, where individuals tend to develop metabolic complications at lower BMI thresholds. Waist circumference, a marker of visceral adiposity, was also higher among females and correlated with elevated FLI, highlighting the contribution of central obesity to NAFLD risk.

Cardio metabolic factors, including triglycerides, fasting blood glucose, HbA1c, hypertension and metabolic syndrome, were significantly associated with NAFLD risk. Triglyceride levels showed a moderate positive correlation with FLI and remained an independent predictor of both FLI and high risk NAFLD. These findings are consistent with the concept of NAFLD as a hepatic manifestation of metabolic syndrome, characterized by altered lipid metabolism and insulin resistance. The high prevalence of metabolic syndrome observed in this cohort further emphasizes the close interplay between metabolic dysfunction and fatty liver disease.

Lifestyle factors also contributed to the observed metabolic burden. Sedentary behavior, reduced physical activity and frequent consumption of fried or fast foods were significantly associated with metabolic syndrome and obesity. Although alcohol consumption was minimal in this cohort, reinforcing the non-alcoholic etiology of fatty liver disease, dietary and physical activity patterns appear to play a substantial role in shaping cardio metabolic risk profiles.

The use of the Fatty Liver Index as a non-invasive assessment tool represents a practical strength of this study. FLI incorporates readily available clinical and biochemical parameters and allows for effective risk stratification in large-scale or resource-limited settings where imaging or liver biopsy may not be feasible. However, reliance on FLI rather than imaging or histology may have led to misclassification in some cases, particularly among individuals in the intermediate-risk category.

Several limitations should be acknowledged. The hospital-based design may limit the generalizability of findings to the broader community. The cross-sectional nature of the analysis precludes causal inferences between identified risk factors and NAFLD. Additionally, dietary intake and physical activity were self-reported and may be subject to recall bias. Despite these limitations, the study's strengths include a well-characterized cohort, comprehensive assessment of cardio metabolic and hormonal factors and robust statistical analyses.

In conclusion, the present study demonstrates a high prevalence of NAFLD risk among middle-aged adults, with obesity, cardio metabolic dysfunction, female gender and post menopausal status emerging as key determinants. These findings highlight the need for early screening, particularly among postmenopausal women and individuals with metabolic risk factors and support the implementation of targeted lifestyle and metabolic interventions to mitigate the growing burden of NAFLD.

STRENGTHS AND LIMITATIONS

Strengths

The present study offers valuable insights into age and gender specific differences in non-alcoholic fatty liver disease risk, with particular emphasis on the influence of menopausal status among women in an Indian clinical setting. The prospective observational design and use of standardized protocols for anthropometric, biochemical, and clinical measurements enhance the internal validity of the findings. Application of the Fatty Liver Index, a well-validated and non-invasive screening tool based on routinely available parameters, improves the clinical applicability of the results. Furthermore, the inclusion of comprehensive cardio metabolic variables and multivariable regression analyses enabled identification of independent predictors of NAFLD risk, strengthening the robustness of the observed associations.

Limitations

The study was conducted in a single tertiary care hospital; hence the results may not be fully generalizable to the broader community. The cross-sectional analytical approach limits causal interpretation of the associations observed between risk factors and NAFLD. Use of the Fatty Liver Index instead of imaging or histopathological confirmation may have led to potential misclassification, particularly among individuals classified as intermediate risk. Lifestyle and behavioural variables were self-reported and are therefore susceptible to recall and reporting bias. In addition, the relatively limited sample size and lack of longitudinal follow-up restrict evaluation of disease progression and long-term outcomes.

CONCLUSION

The present study demonstrates a high burden of non-alcoholic fatty liver disease risk among middle-aged adults, with the majority of participants classified in the intermediate or high-risk categories based on the Fatty Liver Index. Age, obesity, cardio metabolic factors, female gender and post menopausal status emerged as significant determinants of NAFLD risk. In particular, postmenopausal women exhibited higher FLI scores and an increased likelihood of high-risk NAFLD, highlighting the influence of hormonal and metabolic changes on disease susceptibility. These findings underscore the importance of early screening and targeted preventive strategies, especially among individuals with metabolic risk factors and postmenopausal women. The use of non-invasive tools such as the Fatty Liver Index may facilitate timely identification of high-risk individuals and support the implementation of lifestyle and metabolic interventions to mitigate the growing burden of NAFLD.

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Conflict of Interest

The authors declare no conflict of interest.

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