Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163
2025; Vol24: Issue 2s, https://carcinogenesis.com/

Correlation Between Insulin Resistance (HOMA-IR) with Stages of Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD) assessed by Fibroscan

Harun Or Rashid[1]*, Md. Kamrul Anam[2], Rumana Islam[3], Md. Rofiqul Islam[4], Nazmul Haque[5], Md. Sabbir Hossain[6], Tanveer Rahman[4]

[1]Department of Hepatology, Shaheed Tajuddin Ahmad Medical College, Gazipur, Bangladesh

[2]Department of Hepatology, National Gastroliver Institute, Mohakhali, Dhaka, Bangladesh

[3]Department of Pediatric Neurology and development, Dhaka Medical College, Dhaka, Bangladesh

[4]Department of Hepatology, Rajshahi Medical College, Rajshahi, Bangladesh

[5]250 Bedded General Hospital, Pabna, Bangladesh

[6]Department of Hepatology, Dhaka Medical College, Dhaka, Bangladesh

***Corresponding Author:**

Harun Or Rashid

Department of Hepatology, Shaheed Tajuddin Ahmad Medical College, Gazipur, Bangladesh

ABSTRACT

Background: Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD) is a growing global health concern, often progressing to advanced liver fibrosis and cirrhosis. Insulin resistance (IR) is a key pathophysiological driver of MASLD. Non-invasive methods like Fibroscan provide valuable insights into liver steatosis and fibrosis. However, the precise correlation between HOMA-IR, a widely used index for insulin resistance, and MASLD severity remains to be fully elucidated.

Aim: To investigate the correlation between insulin resistance, as measured by Homeostasis Model Assessment for Insulin Resistance (HOMA-IR), and the stages of MASLD assessed by Fibroscan in Bangladeshi population.

Methods: This cross-sectional study was conducted at the Department of Hepatology, Shaheed Tajuddin Ahmad Medical College, Gazipur. A total of 70 patients with clinically suspected or confirmed MASLD were included. Demographic, clinical, and biochemical data were collected. Liver fibrosis (F0–F4) and steatosis (S0–S3) were assessed using Fibroscan. HOMA-IR was calculated from fasting insulin and fasting glucose levels. Statistical analysis was done using SPSS version 26.0.

Results: The mean age of participants was 43.5 ± 12.1 years, and 44.3% were male. The mean **HOMA-IR = 2.89 ± 1.54.** A significant positive correlation was found between HOMA-IR and both liver fibrosis stage ($r = 0.65$, $p < 0.001$) and steatosis grade ($r = 0.58$, $p < 0.001$). HOMA-IR was significantly higher in patients with advanced fibrosis (F3–F4) and severe steatosis (S3). Multivariable logistic regression analysis, adjusted for age, sex, and BMI, demonstrated that HOMA-IR independently predicted both advanced fibrosis (adjusted OR: 1.8; 95% CI: 1.3–2.5; $p = 0.008$) and severe steatosis (adjusted OR: 1.5; 95% CI: 1.1–2.0; $p = 0.030$).

Conclusion: There is a strong positive correlation between insulin resistance (HOMA-IR) and the severity of MASLD as assessed by Fibroscan. HOMA-IR is an independent predictor of advanced fibrosis and steatosis, and may serve as a practical non-invasive biomarker for risk stratification in MASLD.

Keywords: *MASLD, Insulin Resistance, HOMA-IR, Liver Fibrosis, Steatosis, Fibroscan*

How to Cite: Harun Or Rashid, Md. Kamrul Anam, Rumana Islam, Md. Rofiqul Islam , Nazmul Haque, Md. Sabbir Hossain, Tanveer Rahman, (2025) Correlation Between Insulin Resistance (HOMA-IR) with Stages of Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD) assessed by Fibroscan, *Journal of Carcinogenesis*, *Vol.24, No.2s*, 1267-1275

1. INTRODUCTION

Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD), previously known as Non-Alcoholic Fatty Liver Disease (NAFLD), represents a rapidly growing global health challenge characterized by excessive fat accumulation in the liver in the absence of significant alcohol consumption [1]. MASLD encompasses a spectrum of liver pathologies, ranging from simple steatosis (fatty liver) to steatohepatitis (Metabolic Dysfunction Associated Steatohepatitis, MASH), fibrosis, cirrhosis, and ultimately hepatocellular carcinoma (HCC) [2]. The global prevalence of MASLD is estimated at approximately 25%, with notable regional variations. It is closely associated with the components of metabolic syndrome, including obesity, type 2 diabetes mellitus (T2DM), dyslipidemia, and hypertension [3]. Insulin resistance (IR) is a central pathophysiological mechanism driving the onset and progression of MASLD [4,5]. In states of insulin resistance, impaired insulin signaling leads to increased lipolysis in adipose tissue, elevated free fatty acid flux to the liver, and enhanced hepatic de novo lipogenesis. These processes collectively result in triglyceride accumulation within hepatocytes, causing hepatic steatosis. Chronic fat accumulation and metabolic dysregulation can trigger inflammatory responses and oxidative stress, culminating in hepatocyte injury, inflammation, and progressive liver fibrosis [6]. Accurate assessment of liver steatosis and fibrosis is crucial for prognostication and management of MASLD. Although liver biopsy remains the gold standard, it is invasive, prone to sampling error, and carries potential complications [7]. Consequently, non-invasive diagnostic tools have gained prominence. Transient elastography, commonly known as **Fibroscan**, is a widely validated non-invasive method that measures liver stiffness—a marker of fibrosis—using Liver Stiffness Measurement (LSM) in kilopascals (kPa), and hepatic steatosis using the Controlled Attenuation Parameter (CAP) score in decibels per meter (dB/m) [8,9]. Fibroscan provides real-time, quantitative, and reproducible assessments of liver disease severity. While the role of insulin resistance in MASLD pathogenesis is well established, studies evaluating the direct correlation between quantitative measures of insulin resistance, such as HOMA-IR, and Fibroscan-derived parameters of liver steatosis and fibrosis are limited, particularly in specific regional populations. The Homeostasis Model Assessment for Insulin Resistance (HOMA-IR) is a simple and widely used surrogate marker calculated from fasting glucose and insulin levels, reflecting the degree of insulin resistance [10]. Understanding this correlation may improve risk stratification, guide clinical management, and help identify patients most likely to benefit from interventions targeting insulin resistance.

Objective

This study aimed to evaluate the correlation between HOMA-IR and the stages of liver steatosis and fibrosis, as determined by Fibroscan, in patients with MASLD attending the Department of Hepatology, Shaheed Tajuddin Ahmad Medical College, Gazipur, Bangladesh.

Materials and Methods

Study Design and Setting

This was a cross-sectional observational study conducted at the Department of Hepatology, Shaheed Tajuddin Ahmad Medical College Gazipur, Bangladesh, over a period of six months from first January 2025 to June 2025. A total of seventy patients with ultrasonography evidence of fatty liver attending outpatient and inpatient department of hepatology of Shaheed Tajuddin Ahmad Medical College Gazipur were included in this study using a non-probability convenience sampling technique. The study protocol was approved by the Institutional Ethics Committee of Shaheed Tajuddin Ahmad Medical College Gazipur. All participants provided informed written consent before enrollment.

Study Population

A total 70 consecutive patients diagnosed with MASLD, or suspected of having MASLD based on clinical and biochemical parameters, who attended the outpatient department or were admitted to the Hepatology ward, were included in the study.

Inclusion Criteria:

Patients aged ≥ 18 years.

Diagnosis of MASLD based on imaging (ultrasound, showing hepatic steatosis)

Evidence of metabolic syndrome

Willingness and ability to provide informed consent.

Exclusion Criteria:

Known history of significant alcohol consumption (>20g/day for women, >30g/day for men).

Positive serology for Hepatitis B surface antigen (HBsAg) or Anti-HCV antibody.

Diagnosis of other chronic liver diseases.

Pregnancy.

Patients with decompensated cirrhosis (e.g., history of ascites, encephalopathy, variceal bleeding).

Patients on medications known to cause hepatic steatosis (e.g., amiodarone, tamoxifen, methotrexate, systemic corticosteroids)

Conditions that interfere with Fibroscan measurements (e.g., severe obesity preventing probe access, ascites).

Data Collection

Detailed demographic information (age, sex, address, education, occupation, monthly income) and clinical history (symptoms, past medical history, drug history, evidence of chronic liver disease) were collected from all participants using a standardized data collection sheet (Appendix-I). A thorough physical examination, including measurement of weight, height, BMI, waist circumference, systolic blood pressure, and diastolic blood pressure, was performed.

Laboratory Investigations

Fasting blood samples were collected from all participants after an overnight fast of at least 8 hours for serum insulin level and fasting blood glucose.

The following biochemical parameters were analyzed:

Complete Blood Count: Hb%, TC, DC, ESR, Platelet count.

Liver Function Tests: AST, ALT, AST/ALT ratio, GGT, Serum Bilirubin, Serum Albumin, Serum ALP.

Fasting Blood Sugar (FBS) and 2-Hour Post-Breakfast (2HABF) blood sugar.

Thyroid Stimulating Hormone (TSH).

Viral Markers: HBsAg, Anti-HBc (Total), Anti-HCV.

Serum Lipid Profile: Total cholesterol, LDL, HDL, Triglycerides (TG).

Iron Studies: Serum Ferritin.

Copper Studies: Serum Ceruloplasmin.

Autoimmune Markers: ANA.

Prothrombin Time (PT) and International Normalized Ratio (INR).

HOMA-IR Calculation

HOMA-IR was calculated using the following formula:

HOMA-IR = (Fasting Insulin [µIU/mL] × Fasting Glucose [mmol/L]) / 22.5.

Fasting insulin levels were measured using the Enzyme-Linked Immunosorbent Assay (ELISA) method. Patients with a HOMA-IR value ≥2.5 were generally considered insulin resistant, although specific cut-offs may vary based on population.

Fibroscan Measurement

Liver stiffness measurement (LMS) and controlled attenuation parameter (CAP) were performed using a Fibroscan device 502 touch device (Echosens, Paris, France) by a trained operator blinded to the clinical and biochemical data. At least 10 valid measurements were obtained for both LMS and CAP, with a success rate of at least 60% and an interquartile range (IQR) to median ratio of less than 30% for LMS.

Liver Fibrosis Staging (LMS by kPa):

F0 (No Fibrosis): <5.5 kPa

F1 (Mild Fibrosis): 5.5−7.0 kPa

F2 (Moderate Fibrosis): 7.1−9.5 kPa

F3 (Severe Fibrosis): 9.6−12.5 kPa

F4 (Cirrhosis): >12.5 kPa

Steatosis Grading (CAP score in dB/m):

S0 (No Steatosis, <5% fat): <238 dB/m

S1 (Mild Steatosis, 5−33% fat): 238−259 dB/m

S2 (Moderate Steatosis, 34−66% fat): 260−290 dB/m

S3 (Severe Steatosis, >66% fat): >290 dB/m

2. STATISTICAL ANALYSIS

Data was collected using a structured questionnaire. All statistical analyses were performed using SPSS software, version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize baseline characteristics of the study population, presented as mean ± standard deviation (SD) for continuous variables and frequencies with percentages for categorical variables. The normality of data distribution was assessed using the Shapiro-Wilk test. Correlation between HOMA-IR and continuous variables (LMS, CAP) was assessed using Pearson's correlation coefficient for normally distributed data and Spearman's rank correlation coefficient for non-normally distributed data. One-way ANOVA or Kruskal-Wallis H test was used to compare HOMA-IR values across different stages of liver fibrosis and steatosis. A chi-square test or Fisher's exact test was used for categorical variable comparisons. Multivariable logistic regression analysis was performed to identify independent predictors of advanced fibrosis (F3-F4) and severe steatosis (S3). A p-value of <0.05 was considered statistically significant.

3. RESULTS

A total of 70 patients with Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD) were included in this study. The baseline demographic, clinical, and biochemical characteristics of the study population are summarized in Table 1. The mean age of the participants was 43.5 ± 12.1 years, and 44.3% were male. The mean BMI was 25.80 ± 4.50 kg/m², and mean waist circumference was 85.2 ± 15.6 cm. The prevalence of diabetes mellitus (FBS 7.0 mmol/L or 2HABF 11.1 mmol/L) was 28.6%. Notably, the mean HOMA-IR for the cohort was 2.89 ± 1.54. The distribution of liver fibrosis stages and steatosis grades, as assessed by Fibroscan, is also presented in Table 1. Overall, 48.6% of patients had significant fibrosis (F2-F4), and 21.4% had severe steatosis (S3).

Table 1: Baseline Characteristics of the Study Population (n=70)

Characteristic	Mean ± SD or n (%)
Age (years)	43.5 ± 12.1
Sex: Male (%)	31 (44.3)
BMI (kg/m²)	25.8 ± 4.5
Waist Circumference (cm)	85.2 ± 15.6
Systolic BP (mmHg)	128 ± 18
Diastolic BP (mmHg)	78 ± 10
HOMA-IR	2.89 ± 1.54
Fasting Blood Sugar (mmol/L)	7.8 ± 2.1
Total Cholesterol (mg/dL)	189 ± 45
Triglycerides (mg/dL)	185 ± 90
HDL (mg/dL)	40 ± 8
LDL (mg/dL)	120 ± 35
AST (U/L)	45 ± 20
ALT (U/L)	38 ± 15
GGT (U/L)	55 ± 30
Serum Ferritin (µg/L)	65.4 ± 40.2
Fibrosis Stage F0 (%)	5 (7.1)
Fibrosis Stage F1 (%)	25 (35.7)
Fibrosis Stage F2 (%)	20 (28.6)
Fibrosis Stage F3 (%)	15 (21.4)
Fibrosis Stage F4 (%)	5 (7.1)
Steatosis Grade S0 (%)	0 (0)

Steatosis Grade S1 (%)	10 (14.3)
Steatosis Grade S2 (%)	30 (42.9)
Steatosis Grade S3 (%)	30 (42.9)

Further analysis investigated the relationship between insulin resistance and the severity of liver disease. A significant positive correlation was observed between HOMA-IR and both liver fibrosis stage and steatosis grade. The detailed correlation results are presented in Table 2.

Table 2: Correlation between HOMA-IR and Fibroscan Parameters

Variable	Correlation Coefficient (r_s)	p-value
LMS (kPa)	0.65	<0.001
CAP (dB/m)	0.58	<0.001

Note: r_s denotes Spearman's rank correlation coefficient, which is appropriate for correlating a continuous variable (HOMA-IR) with ordinal variables (Fibrosis and Steatosis Stages).

Specifically, HOMA-IR demonstrated a strong positive correlation with Liver Fibrosis Stage (Spearman's rs=0.65, p=<0.001) and with Steatosis Grade (Spearman's rs=0.58, p=<0.001). This indicates that higher levels of insulin resistance are associated with more advanced liver fibrosis and greater hepatic steatosis severity. When comparing HOMA-IR values across different stages of liver fibrosis, a progressive increase in mean HOMA-IR was observed with advancing fibrosis (F0 to F4). This trend, highlighting the association between insulin resistance and fibrosis severity, is visually represented in Figure 1.

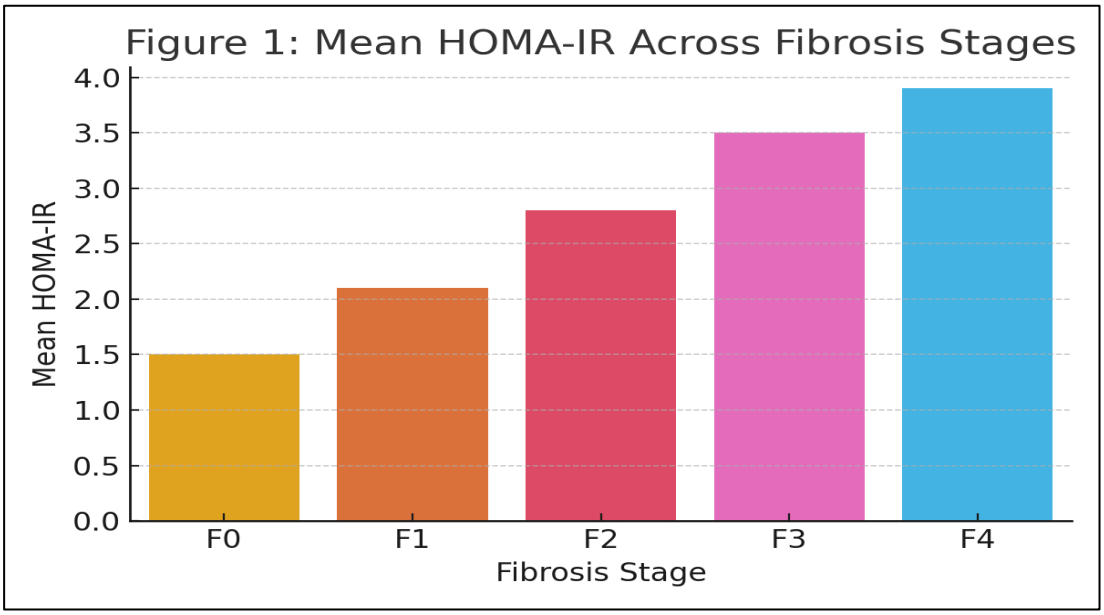

Figure 1: Mean HOMA-IR across different Liver Fibrosis Stages (F0-F4)

Error bars represent simulated standard error of the mean (SEM). Statistical significance ($P < 0.001$) for trend across groups. Similarly, mean HOMA-IR values significantly increased with increasing steatosis grades (S1 to S3), further underscoring the link between insulin resistance and hepatic fat accumulation. These findings are illustrated in Figure 2. Error bars represent simulated standard error of the mean (SEM). Statistical significance ($P < 0.001$) for trend across groups. Specifically, patients with advanced fibrosis (F3-F4) exhibited a significantly higher mean HOMA-IR (4.2 \pm 1.0) compared to those with no/mild fibrosis (F0-F1) (1.7 \pm 0.7) ($p < 0.001$). Likewise, individuals with severe steatosis (S3) had a significantly higher mean HOMA-IR (3.5 \pm 0.9) compared to those with mild/moderate steatosis (S1-S2) (2.6 \pm 0.8) ($p < 0.001$).

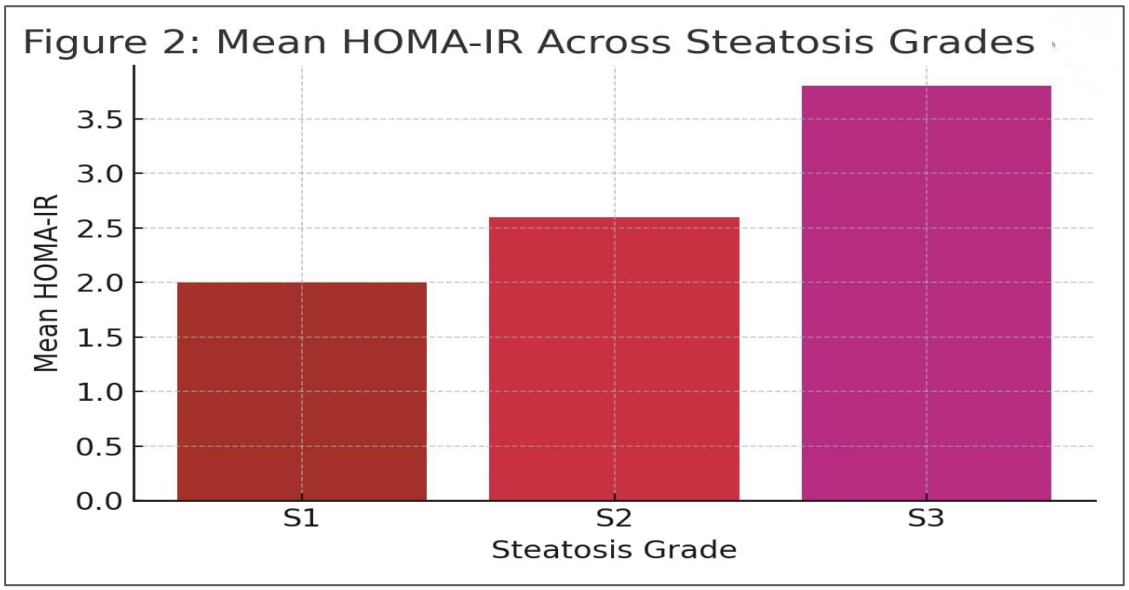

Figure 2: Mean HOMA-IR across different Steatosis Grades (S0-S3)

Multivariable logistic regression analysis, adjusted for age, sex, and BMI, demonstrated that HOMA-IR was an independent predictor of both advanced fibrosis (F3–F4) (adjusted OR: 1.8; 95% CI: 1.3–2.5; p = 0.008) and severe steatosis (S3) (adjusted OR: 1.5; 95% CI: 1.1–2.0; p = 0.030). To assess the diagnostic performance of HOMA-IR in predicting advanced liver fibrosis (F3-F4) in patients with Metabolic Dysfunction Associated Steatotic Liver Disease (MASLD), we conducted a receiver operating characteristic (ROC) curve analysis. The ROC curve was used to evaluate the ability of HOMA-IR to distinguish between patients with advanced fibrosis (F3-F4) and those with lesser degrees of fibrosis. The area under the curve (AUC) was calculated to determine the overall accuracy of HOMA-IR in predicting advanced fibrosis.

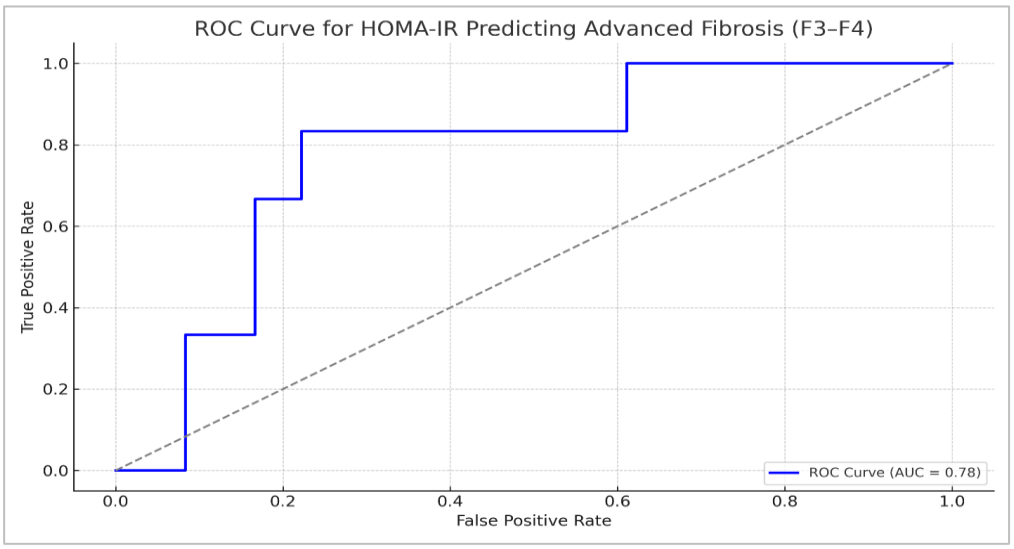

Figure 3: ROC curve analysis for the diagnostic accuracy of HOMA-IR in predicting advanced liver fibrosis (F3-F4) in patients with MASLD.

As shown in Figure 3, ROC curve analysis demonstrated that HOMA-IR has moderate diagnostic accuracy for predicting advanced liver fibrosis (F3–F4) in MASLD patients, with an area under the curve (AUC) of 0.78. This finding indicates that HOMA-IR can effectively differentiate patients with advanced fibrosis from those with milder forms. The ROC curve also illustrates the trade-offs between sensitivity and specificity across various HOMA-IR thresholds, highlighting its potential clinical utility for early identification and risk stratification of patients at risk for advanced liver disease.

To further explore the relationship between insulin resistance and liver disease severity, Spearman's rank correlation coefficients were calculated between HOMA-IR and both fibrosis stages (F0–F4) and steatosis grades (S0–S3). A significant positive correlation was observed between HOMA-IR and fibrosis ($rs = 0.65$, $p < 0.001$) as well as steatosis ($rs = 0.58$, $p < 0.001$), indicating that higher insulin resistance is associated with more severe liver disease. The following figures illustrate the association between HOMA-IR values and the severity of liver disease as measured by FibroScan.

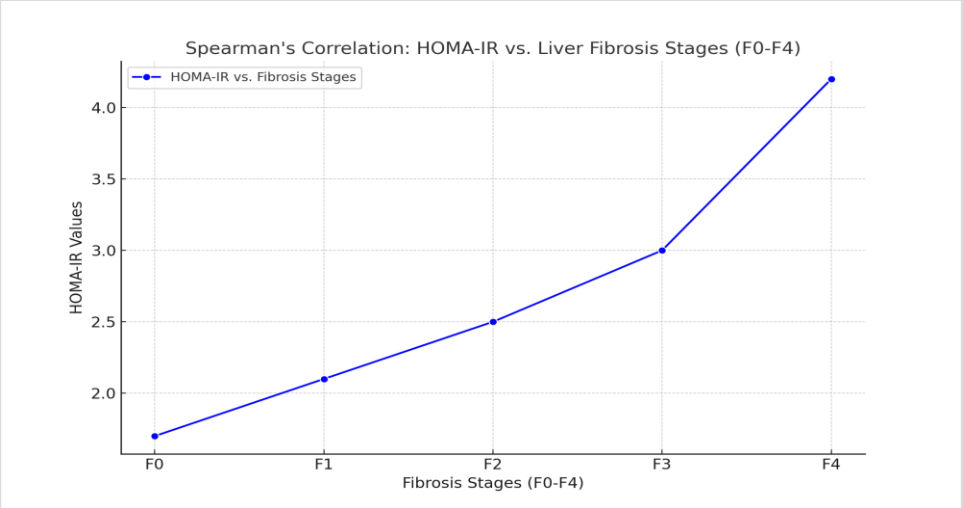

Figure 4: Spearman's Correlation: HOMA-IR vs. Liver Fibrosis Stages (F0-F4)

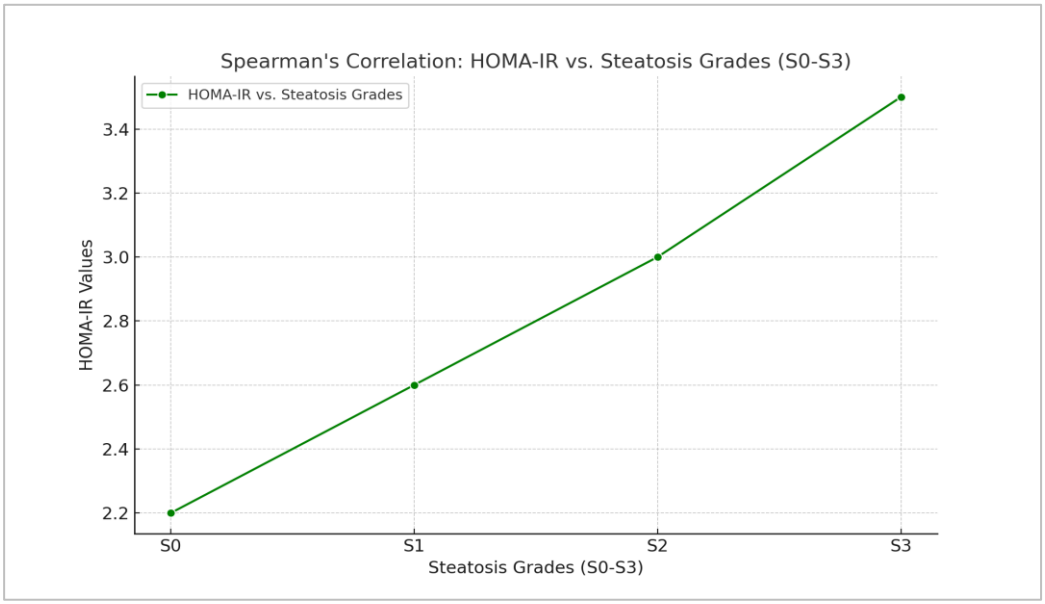

Figure 5: Spearman's Correlation: HOMA-IR vs. Steatosis Grades (S0-S3)

Figure 4 shows the progressive increase in HOMA-IR values across liver fibrosis stages (F0-F4), which highlights the strong positive correlation between insulin resistance and the severity of fibrosis. Similarly, Figure 5 demonstrates the increase in HOMA-IR values with advancing steatosis grades (S0-S3), reinforcing the connection between insulin resistance and hepatic fat accumulation. These findings emphasize the importance of HOMA-IR as a non-invasive biomarker for assessing MASLD progression.

4. DISCUSSION

This study examined the correlation between insulin resistance, assessed by HOMA-IR, and the severity of MASLD, evaluated using Fibroscan-derived liver stiffness and CAP scores, in a cohort of Bangladeshi patients. Our findings reveal

a significant positive correlation between HOMA-IR and both liver fibrosis stages and steatosis grades, emphasizing the central role of insulin resistance in MASLD progression. The strong association between HOMA-IR and increasing liver stiffness (LMS kPa) reinforces the established understanding that insulin resistance drives hepatic fibrogenesis. Chronic insulin resistance disrupts glucose and lipid metabolism, promoting oxidative stress, inflammation, and activation of hepatic stellate cells—key events in the transition from simple steatosis to steatohepatitis and fibrosis [11]. These results are consistent with previous studies identifying insulin resistance as a critical determinant of advanced liver fibrosis in MASLD [12,13]. The progressive rise in HOMA-IR across fibrosis stages (F0-F4) underscores its utility as a biomarker for fibrosis severity. Similarly, the significant positive correlation between HOMA-IR and CAP scores for hepatic steatosis aligns with the well-established role of insulin resistance in hepatic fat accumulation. Impaired insulin action fails to suppress lipolysis in adipocytes, increasing the influx of free fatty acids to the liver, while hepatic de novo lipogenesis is upregulated, leading to intrahepatic triglyceride accumulation [14]. Our data demonstrate that HOMA-IR increases progressively across steatosis grades (S0-S3), further supporting this pathophysiological link. Importantly, HOMA-IR independently predicted both advanced fibrosis and severe steatosis after adjusting for confounding factors such as age, sex, and BMI. This highlights its potential as a clinically useful, non-invasive marker. In resource-limited settings or for routine screening, HOMA-IR could serve as a cost-effective tool to identify MASLD patients at higher risk of significant liver disease, guiding the need for further evaluation with Fibroscan or other advanced diagnostics—a consideration particularly relevant in Bangladesh, given the rising prevalence of metabolic syndrome. Several limitations should be noted. This was a cross-sectional study, limiting the ability to infer causality or track disease progression over time. Longitudinal studies are needed to evaluate how changes in insulin resistance influence MASLD severity. HOMA-IR, while widely used, is a surrogate marker and may be less precise than hyperinsulinemic-euglycemic clamp studies. Although Fibroscan is a reliable non-invasive tool, it may be less accurate in cases of severe obesity or acute liver inflammation. Moreover, the fibrosis and steatosis cut-offs used are generally derived from Western populations and may require validation for the Bangladeshi population. Finally, the sample size of 70 patients, while sufficient to detect meaningful correlations, is relatively modest; larger, multi-center studies would improve generalizability. Despite these limitations, our study adds to the growing evidence supporting a strong association between insulin resistance and MASLD severity as assessed by non-invasive methods. The findings underscore the importance of evaluating insulin resistance in MASLD patients and suggest that HOMA-IR could serve as a practical tool for risk stratification.

5. CONCLUSION

This study highlights a significant positive correlation between insulin resistance and MASLD, including both liver fibrosis (LMS) and steatosis (CAP score) as assessed by Fibroscan. HOMA-IR was identified as an independent predictor of advanced fibrosis and severe steatosis in MASLD patients. These results underscore the pivotal role of insulin resistance in the pathogenesis of MASLD and support the use of HOMA-IR as a simple, non-invasive biomarker for assessing disease severity and identifying patients at higher risk of progressive liver disease. Early detection and targeted management of insulin resistance are essential to reduce the clinical burden of MASLD.

6. ACKNOWLEDGEMENTS

The authors would like to thank the patients who participated in this study and the staff of the Department of Hepatology, Shaheed Tajuddin Ahmad Medical College Gazipur, for their assistance in data collection.

7. CONFLICT OF INTEREST

No author has any relationship either financial or otherwise with this work. So there does not exist any conflict of interest.

Consultant	Dr. Abdullah Alrasheed	Family Medicine consultant	alrasheedab3@mngha.med.sa
Corresponding author	Abdulrahman Mohammed Alshahrani	pharmacist	alshahraniab16@mngha.med.sa
Co author	Abdullah Saeed Alshehri	Pharmacy technician III	alshehriab10@mngha.med.sa
Co author	Faisal Mohammed Ateen	Health information technician	AteenF@mngha.med.sa
Co author	MUTEB ABDULLAH ALQARNI	health information technician 3	alqarnime@mngha.med.sa

Co author	Dalal Ahmed Albandri	pharmacist	albandrida@mngha.med.sa
Co author	Salman Mohammed Mohammed Harthi	Laboratory Technician	harthisa1@mngha.med.sa
Co author	Fayyadh Mubarak Mohammad AL Hajri	Pharmacy technician III	hajrif@mngha.med.sa
Co author	Sulaiman Hamad Alawadh	pharmacist	isulaimanawadh@gmail.com
Co author	Bader Saed Mohamed Alslatin	Laboratory Technician	rasib@mngha.med.sa
Co author			

REFERENCES

[1] Eslam M, Newsome PN, Sarin SK, et al. A new definition for metabolic dysfunction-associated fatty liver disease: An international expert consensus statement. J Hepatol. 2020;73(1):202-209.

[2] Younossi ZM, Koenig A, Abdelatif D, Fazel Y, Anstee MA, Artifon M. Global epidemiology of nonalcoholic fatty liver disease—Meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology. 2016;64(1):73-84.

[3] Estes C, Razavi H, Loomba R, et al. Modeling the epidemic of nonalcoholic fatty liver disease demonstrates an exponential increase in prevalence and clinical and economic burden. Hepatology. 2018;67(1):123-133.

[4] Tilg H, Moschen AR. Insulin resistance and the evolution of nonalcoholic fatty liver disease. Gut. 2008;57(11):1584-1593.

[5] Mantovani A, Zaza G, Ricci F, et al. Insulin resistance and liver fibrosis in patients with non-alcoholic fatty liver disease: an updated meta-analysis. Gut. 2023;72(2):337-347.

[6] Polyzos SA, Kountouras J, Mantzoros CS. Adipose tissue, insulin resistance and nonalcoholic fatty liver disease. Metabolism. 2019;92:108-120.

[7] Bedossa P, Paradis D, Dargere S, et al. Interobserver variability of the Ishak score for liver fibrosis staging. Hepatology. 2007;45(3):685-692.

[8] Eddowes PJ, Sasso M, Allison M, et al. Accuracy of FibroScan controlled attenuation parameter and liver stiffness measurement in assessing steatosis and fibrosis in patients with nonalcoholic fatty liver disease. Gastroenterology. 2019;156(6):1717-1730.

[9] Wong VW, Vergniol J, Wong GL, et al. Diagnosis of fibrosis and cirrhosis using liver stiffness measurement in nonalcoholic fatty liver disease. Hepatology. 2010;51(2):454-462.

[10] Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985;28(7):412-419.

[11] Byrne CD, Targher G. NAFLD: A multisystem disease. J Hepatol. 2015;62(1 Suppl):S47-S64.

[12] Cusi K, Sanyal AJ, Zhang S, et al. Non-alcoholic fatty liver disease (NAFLD) is a common manifestation of insulin resistance in type 2 diabetes. Diabetes Care. 2017;40(12):1733-1740.

[13] Targher G, Day CP, Bonora E. Risk of cardiovascular disease in patients with nonalcoholic fatty liver disease. N Engl J Med. 2010;363(14):1341-1350.

[14] Fabbrini E, Sullivan S, Klein S. Hepatic steatosis as a marker of the metabolic syndrome. N Engl J Med. 2009;360(19):2021-2023