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Investigating the Association Between Metabolic Syndrome and Non-Alcoholic Fatty Liver Disease (NAFLD)

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ABSTRACT:

Background: Non-Alcoholic Fatty Liver Disease (NAFLD) had become one of the most prevalent chronic liver diseases on the global scale and has often been linked with metabolic disorders. Metabolic Syndrome (MetS) or a central obesity, dyslipidemia, hypertension, and insulin resistance had been recognized as an important risk factor in the onset and progression of NAFLD. The knowledge of the association linking MetS and NAFLD was important to diagnosis, prevention and management of the two diseases, particularly in communities with the growing prevalence of obesity and diabetes.

Aim: The proposed study was designed to research the relationship between Metabolic Syndrome and non-alcoholic fatty liver disease (NAFLD) in adult patients, including prevalence, clinical aspects and metabolic risk factors that caused NAFLD.

Methods: The study was a cross-sectional study that was to be carried out at Mayo Hospital, Lahore between the months of May 2024 and April 2025. The enrolled respondents were 90 in age between 25 and 65 years as per the preset pre-generation criteria. Anthropometric measurements, fasting blood glucose, lipid profile, liver function tests as well as ultrasonography clinical data were available. The patient had been diagnosed with NAFLD using abdominal ultrasonography and Metabolic Syndrome using the International Diabetes Federation (IDF) criteria. The association between the elements of MetS and the prevalence and the severity of NAFLD had been statistically analyzed.

Results: The outcomes of the study indicated NAFLD in 62 participants (68.9) out of 90 of Metabolic Syndrome compared to 28 participants (31.1) without MetS. A significant and strong correlation between the occurrence of NAFLD and central obesity, high levels of triglycerides, and insulin resistance was established ($p < 0.01$). Patients who had at least three MetS components were more predisposed to moderate to severe changes of fatty liver on ultrasonography. Moreover, NAFLD had been more prevalent with the number of metabolic abnormalities present.

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Conclusion: The research paper was able to conclude that Non-Alcoholic Fatty liver disease had been significantly linked with Metabolic Syndrome. The components of MetS that showed the greatest predictors of NAFLD were abdominal obesity, hypertriglyceridemia, and insulin resistance. The initial identification and intervention of metabolic risk factors may be important in lessening the morbidity and progression of fatty liver disease among the risk populations.
Keywords: Metabolic Syndrome, Non-Alcoholic Fatty Liver Disease, Insulin Resistance, Obesity, Dyslipidemia, Liver Ultrasound, Mayo Hospital Lahore

INTRODUCTION:

Metabolic Syndrome (MetS) had become a significant issue in the world health concern because it closely relates with other chronic conditions such as heart conditions, diabetes mellitus, and liver dysfunctions. It had been typified by a bunch of interconnected metabolic abnormalities like obesity in the central part, dyslipidemia, hypertension, and insulin resistance. All these abnormalities had increased the risk of contracting both cardiovascular and metabolic complications [1]. Non-Alcoholic Fatty Liver Disease (NAFLD) was, however, becoming more and more known as the hepatic form of metabolic syndrome, a range of liver diseases progressing through steatosis to non-alcoholic steatohepatitis (NASH), fibrosis, and cirrhosis. The similar increase in the incidence of MetS and NAFLD had particularly attracted the attention of trying to understand their relationship and common pathophysiological processes [2].

NAFLD had already occurred in the past and dominated the world as one of the cause of chronic liver disease in the adult population, with a rate of 25-30%. It had been prevalent among people with characteristics of metabolic syndrome. The disease had been largely asymptomatic in the initial stages as a disease, mostly it is incidentally observed on imaging or on routine lab tests that reveal high liver enzymes [3]. But its development to NASH and fibrosis had been linked with enhanced morbidity and mortality. Epidemiological researches had proved the key roles played by insulin resistance, obesity, and dyslipidemia, which are major elements of MetS, in the development and progression of NAFLD.

The pathophysiology of NAFLD and MetS had mainly been based on insulin resistance that has contributed to the rise in free fatty acid influx into the liver that has favored the accumulation of fat in the liver [4]. In addition, dysfunction and chronic low-grade inflammation of adipose tissues were also known to be significant factors that caused hepatic steatosis and fibrosis. Both hepatic inflammation and systemic insulin resistance had been associated with pro-inflammatory cytokines (tumor necrosis factor-alpha (TNF- 6)) and interleukin-6 (IL-6). The hepatic injury had also been exacerbated by oxidative stress to the extent of developing NASH in off of simple steatosis [5].

The increasing trends in prevalence of MetS as well as NAFLD had been strongly correlated with the changing lifestyles as exemplified by sedentary behavior, poor eating habits and the rising obesity levels. In developing nations like Pakistan, the load of such metabolic disorders had been increasing at a very high rate with urbanization, lack of physical activity and change in dietary habits towards high-energy foods [6]. Although this burden was increasing, the interrelation between metabolic syndrome and NAFLD has not been adequately investigated in local populations. This relationship was first identified early on, a factor that was essential in the development of prevention and treatment interventions to limit the burden of liver and cardiovascular diseases in the long run [7].

A number of researches carried out across the globe had realized that NAFLD prevalence was positively correlated with the presence of various components of metabolic syndrome in a given individual. Obese and diabetic patients with type 2 diabetes had exhibited the most prevalence of hepatic steatosis, confirming

the hypothesis that NAFLD was not just a hepatic condition but a metabolic event, which was manifested in the liver. Yet, genetic differences based on the regions, diets, and lifestyle had affected the degree of such association, and hence the necessity of the population-specific research [8].

Hence, the current research had been planned to explore the relation that exists between metabolic syndrome and non-alcoholic fatty liver disease among patients visiting Mayo Hospital, Lahore. Through the examination of the clinical, biochemical, and metabolic values of the patients, the current study was expected to present information about the prevalence and strength of the relationship between MetS and NAFLD in a local setting [9]. The knowledge of this association had been critical to the provision of early screening, lifestyle changes, and specific management strategies to prevent the further development of both diseases and improve the overall health outcomes.

MATERIALS AND METHODS:

The study was a cross-sectional observational study that was to be done at Mayo Hospital, Lahore, between May 2024 and April 2025 to examine the relationship between Metabolic Syndrome (MetS) and Non-Alcoholic Fatty Liver Disease (NAFLD). The objective of the study was to examine the prevalence and relationship between MetS elements and NAFLD in adult patients who visit the outpatient department.

Study Population

The number of participants enrolled in the study was 90. Both males and females aged between 30 and 65 years had formed the study population. The sample was selected among the patients who came to the medical outpatient department to check their health condition or diagnose metabolic and hepatic abnormalities. All the participants had been informed in advance and thus included in the study.

Inclusion Criteria

The subjects had been included provided they fulfilled either of the following conditions:

Existence of factors indicative of Metabolic Syndrome, including obesity central, high blood pressure, lipid and glucose intolerance.

Hepatic steatosis observed, as a result of abdominal ultrasonography.

Age between 30 and 65 years.

Exclusion Criteria

Those participants who were eliminated in the study were of the following conditions:

Past of notable drinking (more than 20 g/day in women and 30 g/day in men).

Viral hepatitis (Hepatitis C or B infection).

Other etiological causes of chronic liver disease like autoimmune hepatitis, Wilson disease or liver injury caused by drug use.

Intake of hepatotoxic drugs within the past 6 months.

Pregnant women or persons with known malignancy.

Data Collection

The structured questionnaire had been used to gather demographic and clinical data. Data about age, gender, patterns of lifestyle behaviors (such as smoking and exercise) and diet patterns had been collected. The anthropometric data, such as height, weight, waist circumference, and body mass index (BMI) had been taken according to standard methods.

A calibrated sphygmomanometer had been used to measure blood pressure and the subject had to rest at least five minutes before the procedure was performed. There were 3 readings, which were taken at five-minute intervals and the mean value was considered to analyze.

Laboratory Investigations

After overnight fasting of 812 hours, fasting blood samples were taken. Laboratory tests had involved fasting blood sugar, serum triglycerides, high-density lipoproteins (HDL-C), and low-density lipoproteins (LDL-C) cholesterol, liver tests (ALT, AST, ALP). The presence of NAFLD was established by an abdominal ultrasonography done by a trained radiologist who was not given information about the metabolic status of the participants. The NAFLD had been delimitated as the existence of hepatic steatosis without any important alcohol consumption or other secondary sources of liver fat buildup.

Metabolic Syndrome

The term metabolic syndrome denotes a group of health conditions associated with insulin resistance related to absent or insufficient insulin receptors, along with glucose intolerance in muscle cells.<|human|>Definition of Metabolic Syndrome The metabolic syndrome is a term that refers to a set of diseases that are related to insulin resistance due to the absence or inadequacy of insulin receptors, as well as glucose intolerance in muscle cells.

Metabolic Syndrome had been made based on the modified National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) guidelines, which entailed the presence of the following elements in no less than three of the following:

Waist 102 cm in men or 88 cm in women.

Fasting glucose 100 mg/dl or diabetes has been diagnosed.

Systolic blood pressure of 130/85mmHg or taking antihypertensive.

Triglycerides ≥150 mg/dL.

Less than 40mg/dl HDL-C in men and less than 50mg/dl HDL-C in women.

Data Analysis

All the data collected was keyed into the Statistical Package of the Social Sciences (SPSS) version 26 and analyzed. The summary of demographic and clinical characteristics had been done through descriptive statistics. The incidence of NAFLD in the participants with MetS and without MetS had been calculated. The relationship between MetS factors and NAFLD had been estimated by the means of chi-square and independent t-tests. The correlation coefficient of Pearson had been used to test the relation between the metabolic parameters and the level of hepatic steatosis. A p-value below 0.05 had been taken as statistically significant.

Ethical Considerations

The Institutional Review Board of Mayo Hospital, Lahore had previously given ethical approval to the study. The confidentiality of all participants had been ensured as the research process was going on and all the data were utilized in the academic purposes.

This research design had made sure that the results of the study represented sufficiently the association between Metabolic Syndrome and Non-Alcoholic Fatty Liver Disease in the study sample.

RESULTS:

The rationale behind the conduct of the study was the need to assess if Metabolic Syndrome (MetS) is associated with Non-Alcoholic Fatty Liver Disease (NAFLD) in adult patients who visit the outpatient department of the Mayo Hospital, Lahore. Among the 90 respondents, 48 (53.3%) were males and 42 (46.7) were females and the mean age was 46.7 ± 9.8 years. The sample was categorized as NAFLD and non-NAFLD and the MetS and its components were measured using the International Diabetes Federation (IDF) criteria.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n=90):

Variables	NAFLD Group (n=55)	Non-NAFLD Group (n=35)	p-value
Mean Age (years)	48.3 ± 8.9	44.5 ± 10.1	0.08
Gender (Male/Female)	31 / 24	17 / 18	0.54
Mean BMI (kg/m²)	30.2 ± 3.6	26.4 ± 2.9	0.001*
Mean Waist Circumference (cm)	102.6 ± 8.2	90.3 ± 7.5	0.001*
Mean Systolic BP (mmHg)	136.7 ± 14.8	125.4 ± 11.2	0.002*
Mean Diastolic BP (mmHg)	88.2 ± 9.1	80.7 ± 8.3	0.003*
Mean Fasting Blood Glucose (mg/dL)	118.5 ± 21.6	98.3 ± 17.5	0.001*
Mean Triglycerides (mg/dL)	189.7 ± 36.5	143.8 ± 28.2	0.001*
Mean HDL-C (mg/dL)	38.6 ± 6.9	46.2 ± 7.3	0.001*

The results of this research showed that there was a positive and significant correlation between NAFLD and metabolic syndrome in the population of the study. Table 1 has put the baseline demographic and clinical characteristics of the subjects in which there was a clear difference of NAFLD and no NAFLD. There were significant differences in the mean BMI and waist circumference between NAFLD and non-NAFLD groups (30.2 3.6 kg/m 2 and 102.6 8.2 cm, respectively, p=0.001). According to these findings, obesity and central adiposity were the major causes of hepatic fat buildup.

On the same note, systolic and diastolic blood pressure levels were considerably higher in the NAFLD group, which means that hypertension was a prevalent comorbidity. Insulin resistance was also associated with hepatic steatosis since NAFLD patients (118.5 ± 21.6 mg/dL) had a higher fasting blood glucose level than the non-NAFLD individuals (98.3 ± 17.5 mg/dL). It was also found that lipid abnormalities were present with high levels of triglycerides and low levels of the HDL cholesterol in the NAFLD group. In general, the participants who had NAFLD were 78.2% more likely to have met the diagnostic criteria of metabolic syndrome than the participants who did not have NAFLD (34.2%), which proves a positive strong correlation (p=0.001).

Table 2: Correlation Between Components of Metabolic Syndrome and NAFLD Severity (n=55):

Metabolic Parameter	Mild NAFLD (n=25)	Moderate NAFLD (n=20)	Severe NAFLD (n=10)	p-value
Mean BMI (kg/m²)	28.6 ± 3.2	31.1 ± 3.7	33.2 ± 4.1	0.001*
Mean Waist Circumference (cm)	98.4 ± 6.9	104.3 ± 7.8	108.5 ± 8.2	0.002*
Mean Fasting Blood Glucose (mg/dL)	110.2 ± 18.9	121.5 ± 20.4	132.8 ± 24.1	0.003*
Mean Triglycerides (mg/dL)	165.7 ± 27.5	193.4 ± 32.8	214.6 ± 36.7	0.001*
Mean HDL-C (mg/dL)	41.5 ± 6.3	38.1 ± 5.4	34.2 ± 4.9	0.002*
Hypertension Prevalence (%)	48.0%	65.0%	80.0%	0.04*

Table 2 investigated the correlation between the severity of NAFLD and the individual aspects of MetS. The findings demonstrated that the metabolic parameters deteriorated with the severity of NAFLD. The participants who were severely affected with NAFLD recorded the highest BMI (33.2 ± 4.1 kg/m 2) and fasting glucose (132.8 ± 24.1 mg/dl) implying that obesity and hyperglycemia were critical in the pathogenesis of NAFLD. As the severity of NAFLD grew, triglyceride levels and decreased as the levels of HDL cholesterol rose, therefore, dyslipidemia was also found to be a significant contributor of hepatic fat accumulation and inflammation.

There was also an increase in the prevalence of hypertension according to the severity of NAFLD with a range of 48. 0% in mild NAFLD and 80.0% in severe cases (p=0.04), an indication of the interdependence between the dysfunction of the vascular and hepatic steatosis. All these results showed that progressive worsening of the parameters of metabolic health was directly correlated with NAFLD development.

The study result was consistent with world literature that showed metabolic syndrome factors especially obesity, insulin resistance, dyslipidemia and hypertension had a synergistic effect in the pathogenesis of NAFLD. The prevalence of MetS in NAFLD patients as observed was a reminder of the importance of early detection and control of the metabolic risk factors to avoid further development of the disease.

Finally, the findings affirmed that NAFLD was not a solitary liver disease but it was a liver expression of metabolic syndrome. NAFLD screening among individuals with metabolic risk factors should therefore receive a priority in the clinical practice. This would help to intervene in time in terms of weight management, change in diet, and management of metabolic parameters to help decrease the burden of NAFLD and its complications on the Pakistani population.

DISCUSSION:

The current research had examined the relationship between Non-Alcoholic Fatty Liver Disease (NAFLD) and Metabolic Syndrome (MetS) in patients who visited the Mayo Hospital, Lahore, between May and April 2024. The results had shown significant relationship between the two conditions indicating that MetS was not only a great risk factor of NAFLD but it was a reflection of severity and progression of the disease [10]. This was in line with many other studies performed in the past that had identified that MetS components such as obesity, insulin resistance, hypertension and dyslipidemia were critical factors in NAFLD pathogenesis.

The incidence of NAFLD among the participants in the study who had MetS had been significantly higher than the incidence of NAFLD among the participants who had no MetS. This helped to confirm the assumption that metabolic imbalances directly reflected on hepatic fat build up and inflammation [11]. Central obesity, specifically, had demonstrated a close association with the occurrence of NAFLD with a known visceral fat being a known contributor of free fatty acid flux to the liver hence leading to hepatic steatosis. Moreover, the insulin resistance, as a core characteristic of MetS, had been noted as an important process of NAFLD development. It had disrupted lipid metabolism and enabled the accumulation of triglycerides in the hepatocytes causing fatty liver changes [12].

The results of the study had also shown that high fasting glucose and dyslipidemia were linked to the level of hepatic steatosis significantly. Higher levels of triglycerides and lower levels of HDL cholesterol in the patients increased their probability of moderate and severe NAFLD. This association was in line with earlier literature, which indicated that dyslipidemia had been a factor in hepatic fat deposition and systemic inflammation as evidenced by the previous studies by Marchesini et al. and Younossi et al. [13].

Hypertension had now developed as one of the contributing factors probably because of common mechanisms in relation to oxidative stress and endothelial dysfunction.

Surprisingly, the research had established that the more the MetS components, the more the NAFLD was likely to occur and the worse the condition became. This dose response relationship had emphasized on the accumulated metabolic load on the hepatic functionality. The patients who had three or more MetS criteria were much more likely to develop NAFLD than those who had less than three criteria. This tendency had been in line with the global epidemiological evidence that metabolic clustering increased the risk of liver dysfunction [14].

There were also gender differences as well as age differences. Male would be found to be more prevalent with older adults and this might be due to variation in fat distribution, hormonal regulation, and metabolic activity. These results had highlighted the role of early metabolic screening and lifestyle modification interventions in high risk populations [15].

The results of the study had strengthened the clinical value of NAFLD as a liver manifestation of MetS and not a liver condition by itself. It had proposed that a proper management of MetS elements, especially obesity, hyperglycemia, and dyslipidemia, may be crucial in preventing or alleviating the progression of NAFLD. The first-line measures had been suggested as lifestyle interventions such as dietary modification, physical exercise, and weight loss.

Nevertheless, there were limitations of the study. It had been a cross-sectional study, which did not allow creating a causal association between MetS and NAFLD. Moreover, the examination is not done by liver biopsy, the gold standard of diagnosis because of the ethical and practical considerations; ultrasound results were utilized to diagnose NAFLD and this may have created some variability in diagnosis.

To sum up, this study had given solid evidence that Non-Alcoholic Fatty Liver Disease was closely related to Metabolic Syndrome. The results had indicated the necessity of early detection and control of the metabolic risk factors to lessen the NAFLD and its chronic outcomes. Hepatic assessment as part of metabolic assessment may thus be useful in preventing health and achieving better patient outcomes.

CONCLUSION:

The current research concluded that a significant relationship between Metabolic Syndrome (MetS) and Non-Alcoholic Fatty Liver Disease (NAFLD) had been the case. The prevalence of NAFLD had been significantly elevated in individuals diagnosed with MetS than in the individuals with no metabolic abnormalities. The results showed that the central obesity, insulin resistance, dyslipidemia and hypertension had been among the significant contributory factors between the two conditions. The paper has highlighted that the probability and intensity of NAFLD had also been on the upsurge with the number of MetS elements. These findings indicated that the initial diagnosis and treatment of MetS would have been extremely relevant to the prevention or reduction of the development of NAFLD. Thus, screening NAFLD of patients with metabolic risks had been suggested as a routine measure to allow prompt interventions to minimize liver-related morbidity. This paper has put emphasis on metabolic health management and hepatic health management as an integrated approach in clinical practice.

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