ORIGINAL ARTICLE

Prevalence and Metabolic Predictors of Metabolic Dysfunction-Associated Steatotic Liver Disease in Lean Indian Women with Polycystic Ovary Syndrome versus Those with Obesity

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ABSTRACT

Objective: Metabolic dysfunction-associated steatotic liver disease (MASLD), linked to obesity and insulin resistance (IR), is common in polycystic ovary syndrome (PCOS), but its prevalence in lean individuals with PCOS is not well-established. Hence, the aim of the present study is to investigate the prevalence and predictors of MASLD in lean PCOS patients versus those with obesity. **Materials and methods:** Fifty premenopausal participants diagnosed with PCOS were divided into two groups based on their body mass index (BMI): Group A (lean + normal weight, n = 21) and Group B (overweight + obesity, n = 29). Clinical, anthropometric, and biochemical variables were assessed, including IR, lipid profiles, and hormonal levels. The prevalence of MASLD was determined using ultrasonography (USG). **Statistical analysis:** Mean ± SD (standard deviation) was used for time-varying variables, and percentages for categorical variables. Univariate analysis included Chi-square and independent *t*-tests ($p < 0.05$). Multivariate logistic regression assessed MASLD occurrence in PCOS subjects. Analysis was conducted using Stata software version 14 IC. **Results:** The overall prevalence of MASLD was 40%, with a significantly higher proportion in Group B compared to Group A (62.06% vs. 9.50%; $p < 0.001$). IR was also more common in Group B (79.30% vs. 23.80%; $p < 0.001$). In spite of lower IR, Group A participants also had elevated mean fasting insulin levels (10.32 ± 7.01 mIU/mL), suggesting early metabolic disturbances. Also, Group B participants had significantly higher triglycerides (141.24 ± 42.75 vs. 114.10 ± 31.62 mg/dL; $p = 0.018$), lower high-density lipoprotein cholesterol (43.41 ± 7.57 vs. 51.41 ± 7.12 mg/dL; $p < 0.001$) and higher prevalence of metabolic syndrome (58.62% vs. 4.70%; $p < 0.001$) as compared to Group A participants. **Conclusion:** Our study shows a high prevalence of MASLD in obese women with PCOS, likely due to IR. Lean women with PCOS also exhibited metabolic issues, suggesting they may be at risk. These findings highlight the importance of early metabolic screening and interventions in PCOS women.

Keywords: PCOS, MASLD, fatty liver disease, metabolic dysfunction

Polycystic ovary syndrome (PCOS) is the most common endocrine disorder affecting women of reproductive age, with a significant impact on metabolic and reproductive health[1]. Among the hallmark features of PCOS are insulin resistance (IR) and obesity, which contribute to the pathophysiology of the condition and increase the risk of associated comorbidities, including cardiovascular diseases (CVD) and type 2 diabetes mellitus (T2DM)[1-4]. These metabolic disturbances have led to increased attention on the long-term health risks faced by women with PCOS, particularly as they approach midlife.

Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly known as nonalcoholic fatty liver disease (NAFLD) is a prevalent condition characterized by fat accumulation in the liver in the absence of

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excessive alcohol intake[5]. This spectrum of liver disease includes hepatic steatosis, which is the simple accumulation of fat, and nonalcoholic steatohepatitis (NASH), a more severe form involving inflammation and fibrosis[5,6]. MASLD affects approximately 19% to 34% of the general population with 10% of individuals progressing to NASH[7-9]. Obesity and IR are major risk factors in the development of MASLD, which itself in turn increases the likelihood of developing T2DM and CVD[3,10-12]. These overlapping risk factors suggest a potentially heightened risk for MASLD among women with PCOS, although the full extent of this relationship remains to be fully understood.

The association between PCOS and MASLD has been the subject of several studies, which have highlighted the overlapping metabolic pathways that contribute to both conditions[13-18.] However, many of these studies have been limited by small sample sizes, lack of control groups, or a narrow focus on either obese or normal-weight populations, leaving important gaps in our understanding of the broader relationship between the two. MASLD, traditionally linked to obesity, is also prevalent in lean individuals with metabolic dysfunction, such as IR and visceral adiposity. This is particularly common in Indian population, where lean MASLD is increasingly recognized. In women with PCOS, both obese and lean, metabolic disturbances contribute to liver fat accumulation, highlighting the need for better understanding and screening in this group[18].

Given the high prevalence of both conditions and their combined impact on long-term health, particularly with respect to T2DM and CVD, it is critical to explore how MASLD manifests in women with PCOS across different weight categories. Understanding the factors that contribute to the development of MASLD in this population could help in identifying at-risk individuals and developing targeted prevention strategies. This study aims to investigate the prevalence of MASLD in lean versus obese premenopausal participants with PCOS, as well as to identify the key risk factors associated with the presence of MASLD in this population. Through this approach, we hope to provide valuable insights into the complex interplay between metabolic dysfunction and liver health in women with PCOS.

MATERIALS AND METHODS

A total of 50 premenopausal PCOS patients (sample size was calculated using OpenEpi with an alpha level of 0.05, power of 0.80, and a medium effect size, ensuring adequate power to detect significant differences between obese and non-obese groups) attending the Endocrinology Clinic at Pt. BD Sharma Post Graduate Institute of Medical Sciences, Rohtak between 1st April 2015 and 31st December 2016 were enrolled for the study. An informed written consent was obtained from all patients. Additional consent of one parent was also taken in cases of participants younger than 18 years of age. The study was approved by Institutional Ethical Committee (Ethical clearance No.: IEC/Th/14/MED-03) of Pt. BD Sharma University of Health Sciences.

Inclusion Criteria

Patients diagnosed with PCOS were included in the study. Adult PCOS was characterized using the 2003 PCOS consensus workshop criteria sponsored by the European Society of Human Reproduction and Embryology (ESHRE)/American Society for Reproductive Medicine (ASRM)[19]:

Premenopausal women with confirmed diagnosis of PCOS (with any two of following criteria were enrolled).

- Oligomenorrhea/oligo-ovulation.
- Clinical and/or biochemical signs of hyperandrogenism.
- Ultrasonographic evidence of PCOS.

Oligomenorrhea was defined as absence of menstruation for >35 days. Clinical hyperandrogenism was evaluated by modified Ferriman-Gallwey score ≥8. Criteria for ultrasound diagnosis of PCOS were presence of 12 or more follicles in each ovary measuring 2 ± 9 mm in diameter, and/or increased ovarian volume (>10 mL) in any one of two ovaries.

Exclusion Criteria

Patients with chronic liver disease, viral hepatitis, type 1 and type 2 diabetes, congenital adrenal hyperplasia, androgen secreting adrenal/ovarian tumor, Cushing's syndrome, overt thyroid disorders are excluded from the study. Patients with history of significant alcohol consumption as well as those on medication that are used in the management of PCOS, MASLD, or dyslipidemia were also excluded.

A detailed menstrual history was taken and anthropometric measurements were recorded. Weight and height were recorded with the patients wearing light clothing and without shoes and socks. Accurate balance scales were used and weight was recorded to the nearest 0.1 kg. Height was recorded to the nearest 0.1 cm by using stadiometer. Waist circumference was measured midway between the superior border of the

iliac crest and the lowermost margin of the ribs at the end of normal expiration. Hip circumference was measured around the point with the maximum circumference over the buttocks, with feet fairly close together (about 12-15 cm apart) and weight equally distributed on each leg.

Physical examination for signs of androgen excess and IR was done. Participants with Ferriman-Gallwey scores of ≥8 were considered to have hirsutism[20]. Blood pressure (BP) was measured with mercury sphygmomanometer in the left arm with the patient in sitting position with apparatus at level of heart and arm supported at the level of heart. BP was checked thrice at 5-minute intervals and mean value was taken for the analysis.

In participants with age ≤18 years, BP was categorized as following[21]:

- Normal BP – both systolic BP (SBP) and diastolic BP (DBP) <90th percentile for age.
- Prehypertension – SBP and/or DBP >90th percentile but <95th percentile for age.
- Hypertension – either SBP and/or DBP ≥95th percentile for the age.

For participants >18 years of age, BP was categorized as following[22]:

- Normal BP – SBP <120 mmHg and DBP <80 mmHg.
- Prehypertension – SBP 120-139 mmHg or DBP 80-89 mmHg.
- Hypertension – SBP ≥140 mmHg or DBP ≥90 mmHg.

Investigations included complete hemogram, fasting plasma glucose, fasting plasma insulin, fasting lipid profile, luteinizing hormone, follicle-stimulating hormone, serum total testosterone, and serum dehydroepiandrosterone sulfate (DHEA-S), in all cases. Blood samples were collected in the morning (after overnight minimum 8 hours fasting). Biochemical hyperandrogenism was defined as serum total testosterone level ≥40 ng/dL[23].

Homeostatic model assessment for insulin resistance (HOMA-IR) method was used to determine IR. HOMA-IR values ≥2.5 were taken as indicative of IR[24]. Dyslipidemia was defined in adults (>17 years) by the presence of any one of the following[25]:

- Low-density lipoprotein (LDL) cholesterol ≥130 mg/dL.
- Triglycerides ≥150 mg/dL.
- Total cholesterol ≥200 mg/dL.
- High-density lipoprotein (HDL) cholesterol ≤40 mg/dL.

Dyslipidemia in females <17 years was defined by the presence of any one of the following[26]:

- LDL cholesterol ≥130 mg/dL.
- Triglycerides ≥130 mg/dL.
- Total cholesterol ≥200 mg/dL.
- HDL cholesterol ≤40 mg /dL.

The diagnosis of MASLD was determined based on the presence of hepatic steatosis observed on ultrasonography (USG), in the absence of alcohol consumption (defined as consumption of ≤20 g/day) and excluding other potential causes such as viral hepatitis and drug-induced liver injury. A high-resolution B-mode scanner of Phillips with a 2-5 Hz convex array probe was used in USG. Hepatic steatosis was defined as diffuse increase in fine echoes in liver parenchyma with impaired visualization of intrahepatic vessels and the diaphragm and echogenicity was compared with renal cortex and/or spleen. FibroScan (M Probe, Echosens, Paris) was also done in all patients and liver stiffness was measured in kilopascal (kPa) values to assess for fibrosis[27].

Metabolic syndrome was defined as per the new definition based on the revised criteria as determined by the International Diabetes Federation (IDF)[28]. For the purpose of comparison, participants were divided in two groups: Group A (n = 21), which comprised lean + normal weight participants and Group B (n = 29), which included participants with overweight and obesity. Body mass index (BMI) categories were defined as follows: lean (<18.5 kg/m^2), normal (18.5-22.9 kg/m^2), overweight (23.024.9 kg/m^2), and obesity (≥25 kg/m^2)[29].

Statistical Analysis

Mean and standard deviation (SD) were calculated for continuous variables where data was represented as mean ± SD and percentage was calculated for categorical variables. Univariate analysis included Chi-square tests for association between categorical variables and independent samples *t*-test for comparison of quantitative variables were carried out. P-value of <0.05 was taken as statistically significant.

Multivariate logistic regression analysis was carried out for the dependent variable of NAFLD occurrence in PCOS subjects. Analysis has been performed using Stata Software version 14 IC.

RESULTS

Out of 50 participants, 21 were either lean or normal weight, whereas 29 were overweight or had obesity. The mean age of participants was 22.18 ± 5.35 years. The mean BMI (kg/m^2) in all participants was 25.45 ± 5.34 kg/m^2. Mean BMI, SBP, and DBP of Group B participants were significantly higher as compared to Group A participants (Table 1).

Oligomenorrhea and hirsutism did not differ significantly between the two groups (Table 2). Acanthosis nigricans was more common in Group B participants (55.17% vs. 19.04%; p = 0.010). Metabolic syndrome was considerable higher i.e., 58.62% in Group B participants as compared to only 4.70% in Group A participants (p < 0.001).

Hepatic steatosis (determined by abdominal USG) was present in 20 (40%) out of total 50 participants. It was significantly more common in Group B participants as compared to Group A participants (62.06% vs. 9.50%; p < 0.001) (Table 2).

Mean fasting plasma glucose did not differ significantly between Group A and Group B participants ([91.52 ± 9.64 mg/dL vs. 94.73 ± 10.95 mg/dL, respectively; p = 0.288], Table 3); however, mean serum fasting insulin levels in Group B participants were significantly higher than in Group A participants (18.79 ± 8.41 mIU/mL vs. 10.32 ± 7.01 mIU/mL; p < 0.001). Similarly, average HOMA-IR values were significantly higher for Group B participants as compared to Group A participants (4.45 ± 2.18 vs. 2.35 ± 1.68; p = 0.001). Also, significantly a greater number of participants in Group B had IR as compared to Group A (79.3% vs. 23.8%; p < 0.001).

Mean serum total testosterone values as well as number of participants with biochemical hyperandrogenism (serum total testosterone level ≥40 ng/dL) did not differ significantly between the two group (Table 3). Mean serum alanine transaminase (ALT) values (40.80 ± 18.50 U/L vs. 33.22 ± 23.11 U/L; p = 0.204) as well as mean serum aspartate transaminase (AST) values (37.61 ± 14.75 U/L vs. 31.88 ± 23.50 U/L; p = 0.295) were higher in Group B as compared to Group A participants although

Table 1. Baseline Anthropometric Characteristics of Study Participants

Variable	Mean ± SD or n (%)			P value (Group A vs. Group B)
	All (n = 50)	Group A (n = 21)	Group B (n = 29)	
Age (years)	22.18 ± 5.35	21 ± 3.36	23.03 ± 6.34	0.080
BMI (kg/m^2)	25.45 ± 5.34	20.38 ± 1.73	29.11 ± 3.82	<0.001*
WC (cm)	85.88 ± 10.78	78.95 ± 6.79	90.90 ± 10.44	0.007*
WHR	0.81 ± 0.04	0.79 ± 0.04	0.83 ± 0.04	0.101
SBP (mmHg)	122.82 ± 12.71	115.43 ± 7.70	128.17 ± 13.02	<0.001*
DBP (mmHg)	77.82 ± 7.29	73.43 ± 4.57	81.00 ± 7.29	<0.001*

*Significant p-values.

SD = Standard deviation; n = number of patients; BMI = Body mass index; WC = Waist circumference; WHR = Waist-to-hip ratio; SBP = Systolic blood pressure; DBP = Diastolic blood pressure.

Table 2. Clinical Characteristics of Study Participants

Variable	N (%)			P value
	Total patients (n = 50)	Group A (n = 21)	Group B (n = 29)	
Oligomenorrhea	48 (96)	21 (100)	27 (93.10)	0.219
Hirsutism	36 (72)	13 (61.90)	23 (79.30)	0.179
Acanthosis	20 (40)	4 (19.04)	16 (55.17)	0.010*
Metabolic syndrome	18 (36)	1 (4.70)	17 (58.62)	<0.001*
Hepatic steatosis	20 (40)	2 (9.50)	18 (62.06)	<0.001*

*Significant p-values.

both these differences were not statistically significant. Similarly, although numerically more participants in Group B had transaminitis, difference was again not statistically significant (48.20% vs. 33.30%; p = 0.291).

Mean serum LDL cholesterol values in Group B participants did not differ significantly as compared to Group A participants (104.92 ± 26.75 mg/dL vs. 96.55 ± 21.89 mg/dL; p = 0.246); however, mean serum HDL cholesterol levels were significantly lower in Group B as compared to Group A participants (43.41 ± 7.57 vs. 51.41 ± 7.12 mg/dL; p < 0.001). Also, mean serum triglyceride values were significantly higher in Group B as compared to Group A participants was (141.24 ± 42.75 vs. 114.10 ± 31.62; p = 0.018). More participants in Group B had dyslipidemia as compared to Group A participants (62.10% vs. 19%; p = 0.002) (Table 3).

Table 4 summarizes the differences between participants with MASLD as compared to those without MASLD. Significant differences in MASLD participants were seen with respect to higher BMI, higher mean values of SBP and DBP, higher presence of metabolic syndrome, higher presence of IR, higher mean values of HOMA-IR and higher mean liver stiffness measurement score as measured by FibroScan.

Multivariate logistic regression analysis was carried out for the dependent variable of MASLD occurrence in the study participants. Feature selection for predictor variables was carried out using univariate analysis and all risk factors with p < 0.1 were included in the regression model. Model with 8 predictors had likelihood ratio Chi-square value of 23.72 with p = 0.003 and pseudo-R square showing a variance of 35%. Main predictor for occurrence of MASLD in study subjects was BMI. The odds of MASLD were increased by 25 times in subjects who were overweight or had obesity as compared to normal or lean study subjects when adjusted for other confounding variables including age and Ferriman-Gallwey score (adjusted odds ratio [OR] 25.45; 95% confidence interval [CI]: 1.08-598.09, p = 0.04) and

Table 3. Biochemical and Hormonal Variables in Study Participants

Variable	Total PCOS patients (n = 50) Mean ± SD or N (%)	PCOS		P value
		Group A (n = 21) Mean ± SD or n (%)	Group B (n = 29) Mean ± SD or n (%)	
Fasting plasma glucose (mg/dL)	93.39 ± 10.44	91.52 ± 9.64	94.73 ± 10.95	0.288
Fasting serum insulin (mIU/mL)	15.23 ± 8.85	10.32 ± 7.01	18.79 ± 8.41	<0.001*
HOMA-IR	3.57 ± 2.23	2.35 ± 1.68	4.45 ± 2.18	0.001*
Insulin resistance	28 (56)	5 (23.8)	23 (79.3)	<0.001*
Serum total testosterone (ng/dL)	64.34 ± 22.54	66.13 ± 25.18	63.05 ± 22.54	0.652
Biochemical hyperandrogenism (n)	43 (86)	18 (85.71)	25 (86.20)	0.960
Serum DHEA-S (µg/dL)	250.86 ± 109.88	289.13 ± 123	223.14 ± 91.79	0.035*
LH/FSH ratio	2.19 ± 0.87	2.34 ± 1.10	2.08 ± 0.67	0.316
Serum LDL cholesterol (mg/dL)	101.41 ± 24.94	96.55 ± 21.89	104.92 ± 26.75	0.246
HDL cholesterol (mg/dL)	46.77 ± 8.32	51.41 ± 7.12	43.41 ± 7.57	<0.001*
Serum triglyceride (mg/dL)	129.84 ± 40.44	114.10 ± 31.62	141.24 ± 42.75	0.018*
Dyslipidemia (n)	23 (46)	4 (19)	19 (62.10)	0.002*
ALT (U/L)	37.62 ± 20.68	33.22 ± 23.11	40.80 ± 18.50	0.204
AST (U/L)	35.21 ± 18.92	31.88 ± 23.50	37.61 ± 14.75	0.295
Transaminitis (n)	21 (42)	7 (33.30)	14 (48.20)	0.291
Liver stiffness measurement (kPa)	5.03 ± 2.30	4.39 ± 1.94	5.50 ± 2.46	0.092

*Significant p-values.

PCOS = Polycystic ovary syndrome; HOMA-IR = Homeostasis model assessment of insulin resistance; DHEA-S = Dehydroepiandrosterone sulfate; LH = Luteinizing hormone; FSH = Follicle-stimulating hormone; LDL = Low-density lipoprotein; HDL = High-density lipoprotein; ALT = Alanine transaminase; AST = Aspartate transaminase.

Table 4. Comparison of Clinical, Anthropometric, Biochemical Variables Between PCOS Subjects With and Without MASLD

Variable	PCOS with MASLD (n = 20) Mean ± SD or N (%)	PCOS without MASLD (n = 30) Mean ± SD or N (%)	P value
Age (years)	23.12 ± 7.12	21.10 ± 3.48	0.08
BMI (kg/m^2)	29.32 ± 5.17	22.87 ± 3.66	<0.001*
Oligomenorrhea (n)	20 (100)	28 (93.30)	0.239
Hirsutism (n)	13 (65)	23 (76.70)	0.368
Acanthosis (n)	10 (50)	10 (33.3)	0.239
Metabolic syndrome (n)	12 (60)	6 (20)	0.004*
SBP (mmHg)	128.45 ± 12.60	119.07 ± 11.50	0.009*
DBP (mmHg)	81.75 ± 5.95	75.20 ± 6.98	0.001*
Insulin resistance	15 (75)	13 (43.30)	0.027*
Dyslipidemia	12 (60)	10 (33.30)	0.065
Fasting plasma glucose (mg/dL)	94.77 ± 10.55	92.47 ± 10.44	0.451
HOMA-IR	4.56 ± 2.44	2.91 ± 1.82	0.008*
Total testosterone (ng/dL)	66.82 ± 25.76	62.69 ± 22.14	0.547
LDL cholesterol (mg/dL)	102.74 ± 28.89	100.52 ± 22.41	0.762
HDL cholesterol (mg/dL)	44.20 ± 7.37	48.49 ± 8.60	0.074
Triglyceride (mg/dL)	139.25 ± 39.88	123.57 ± 40.25	0.182
ALT (U/L)	41.00 ± 17.74	35.36 ± 22.43	0.350
AST (U/L)	38.10 ± 13.78	33.28 ± 21.69	0.383
Transaminitis (n)	11 (55)	10 (33.30)	0.128
LH/FSH ratio	2.30 ± 0.92	2.12 ± 0.85	0.472
DHEA-S (µg/dL)	228.26 ± 84.77	265.93 ± 122.9	0.239
FG score	10 ± 4.36	9.97 ± 2.88	0.974
FibroScan (kPa)	6.05 ± 2.45	4.35 ± 1.96	**0.009***

*Significant p-values.

PCOS = Polycystic ovary syndrome; MASLD = Metabolic dysfunction-associated steatotic liver disease; n = Number of patients; SD = Standard deviation; BMI = Body mass index; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HOMA-IR = Homeostasis model assessment of insulin resistance; LDL = Low-density lipoprotein; HDL = High-density lipoprotein; ALT = Alanine transaminase; AST = Aspartate transaminase; LH = Luteinizing hormone; FSH = Follicle-stimulating hormone; DHEA-S = Dehydroepiandrosterone sulfate; FG = Ferriman-Gallwey.

Table 5. Adjusted Odds Ratio for the Outcome of NAFLD Using Multivariate Logistic Regression Analysis

MASLD	OR	SE	Z-score	P value	95% CI
Insulin resistance					
Absent	1	1			0.17-7.50
Present	1.15	1.10	0.14	0.89	
Metabolic syndrome					
Absent	1	1			0.26-13.89
Present	1.90	1.93	0.63	0.53	
Dyslipidemia					
Absent	1	1			0.16-5.08
Present	0.89	0.79	–0.13	0.90	
BMI (kg/m^2)					
Group A (normal + lean)	1	1			1.08-598.09
Group B (overweight + obese)	25.45	40.99	2.01	0.04#	
Blood pressure (mmHg)					
Normal	1	1			0.08-13.40
High	1.04	1.35	0.03	0.98	
Age in years	1.06	0.10	0.70	0.49	0.89-1.27
FG score	0.88	0.11	–1.03	0.31	0.69-1.12

#Significant p-value.

MASLD = Metabolic dysfunction-associated steatotic liver disease; OR = Odds ratio; SE = Standard error; CI = Confidence interval; BMI = Body mass index; FG = Ferriman-Gallwey.

this increase was statistically significant. Univariately significant predictors such as IR, metabolic syndrome, dyslipidemia, and hypertension lost their statistical significance when adjusted with other confounding variables (Table 5).

DISCUSSION

Our study investigated the prevalence and predictors of MASLD in premenopausal participants with PCOS, comparing lean and normal weight individuals versus those with overweight and obesity. We found that the prevalence of hepatic steatosis was significantly higher in Group B compared to Group A, which aligns with the established literature highlighting the role of obesity and IR in the development of MASLD[7,8,30]. Specifically, 62.06% of the Group B participants with PCOS had

MASLD, compared to just 9.50% in the lean and normal weight group. This finding underscores the significant metabolic risks associated with overweight and obesity in women with PCOS, reinforcing the need for careful monitoring of liver health in this population.

In terms of metabolic disturbances, our data demonstrated that IR was more prevalent in women with PCOS who had obesity. The mean HOMA-IR was significantly higher in Group B compared to Group A participants, which corresponds to a higher incidence of IR in the overweight and obese women versus the lean and normal weight group. IR has long been associated with both PCOS and the development of MASLD, suggesting a critical shared pathophysiological mechanism between these conditions[1,5]. These findings are consistent with prior studies indicating that IR may promote hepatic fat accumulation, thereby increasing the risk of MASLD and its more severe forms, such as NASH[12,31].

While obesity and IR are strongly linked with the development of MASLD in PCOS, our study also revealed important information regarding the biochemical profiles in the lean and normal weight cohort. Although lean and normal weight participants with PCOS exhibited lower levels of IR, they still demonstrated biochemical signs of metabolic dysregulation. For instance, despite normal fasting glucose levels, lean women had elevated mean fasting insulin levels (10.32 ± 7.01 mIU/mL), suggesting early stages of IR that could potentially predispose them to liver fat accumulation. Moreover, there was a higher prevalence of clinical hyperandrogenism in both the group (>85%), with no significant differences between the group. However, the relationship between elevated androgen levels and MASLD remains complex and requires further investigation to elucidate the precise mechanisms.

The hormonal and lipid profiles of our study participants also revealed notable differences between the groups. Group B participants significantly had higher triglyceride levels along with significantly lower HDL cholesterol levels. These findings are consistent with the higher prevalence of dyslipidemia in participants with overweight and obesity and further emphasize the metabolic risks associated with obesity in PCOS women[10,11,32]. On the other hand, despite having a favorable lipid profile, lean women still exhibited other metabolic disturbances, such as higher DHEA-S levels, which have been linked to increased androgen bioavailability and could be another factor contributing to the development of MASLD in lean women with PCOS[15].

Interestingly, the presence of transaminitis (elevated ALT and AST) was observed in both groups, with a higher proportion of those with obesity (48.20%) compared to lean women (33.3%), though this difference was not statistically significant. Elevated liver enzymes are often indicative of liver damage or inflammation, and their higher prevalence among participants with obesity might suggest more pronounced liver dysfunction. This finding highlights the importance of monitoring liver function in women with PCOS, especially those who have obesity, as MASLD could progress to more severe liver conditions, such as NASH or fibrosis, if left untreated.

Additionally, we observed that a higher proportion of women with obesity had acanthosis nigricans (55.17% vs. 19.04%), a condition associated with IR and metabolic syndrome. This finding further corroborates the notion that obesity in PCOS is closely tied to IR, which plays a key role in the development of MASLD[33]. In contrast, only one lean woman in our study exhibited metabolic syndrome, further supporting the concept that obesity significantly contributes to the higher metabolic and liver-related risks in PCOS.

In our study, multivariate logistic regression analysis was performed to investigate the predictors of MASLD occurrence in PCOS subjects. The results indicated that BMI was the main predictor for the development of MASLD in this population. This finding is consistent with previous studies suggesting that lifestyle changes, including diet, weight loss, and exercise, can improve outcomes in PCOS patients with MASLD[15].

A limitation of our study was its small sample size. Larger studies evaluating MASLD in phenotypically different PCOS are needed for the most appropriate screening method and effective interventions. Another limitation of the study was the inability to perform liver biopsy, which is considered the gold standard for diagnosis of MASLD. USG is the most widely used imaging method, which is noninvasive, less time consuming, feasible and cost-effective for detecting fatty liver with 91% sensitivity and 93% specificity in presence of >30% hepatic steatosis. However, for grading of severity of hepatic steatosis and detection of inflammation and fibrosis, liver biopsy is required. Although several biomarkers are, in general, useful for the diagnostic evaluation of a patient with suspected MASLD, they lack the specificity and sensitivity to distinguish fatty liver from NASH and to determine the presence and stage of fibrosis[34].

The key strength of our study is that we performed liver FibroScan on all the study participants. Limited publications are available in the literature regarding

the use of this technique to assess liver stiffness in this population. Additionally, we compared the prevalence of MASLD between lean women with PCOS and those with PCOS and obesity, addressing a gap in the literature, as no previous studies in India have explored this comparison. This unique approach enhances the relevance and applicability of our findings for understanding liver health in PCOS patients.

CONCLUSION

The present study emphasizes the crucial role of obesity and IR in the development of MASLD in women with PCOS. Even though lean women with PCOS may not exhibit overt signs of metabolic syndrome, they still display subtle metabolic disruptions that could predispose them to liver fat accumulation over time. Given the high prevalence of both PCOS and MASLD, our findings suggest the need for early screening and personalized intervention strategies, particularly in women with PCOS, who have overweight or obesity. Future studies should explore the underlying mechanisms that drive liver fat accumulation in lean women with PCOS and assess the long-term risks associated with these metabolic disturbances.

Conflict of Interest: None.

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