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Research Article

Urban Women with PCOS have Unfavorable Anthropometric and Lipid Profiles: A Call for Action

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Abstract

Management of PCOS requires knowledge about clinical and biochemical markers since PCOS characteristically has several concurrent metabolic disturbances. Overweight/obesity, impaired glucose tolerance, and type 2 diabetes mellitus are commonly reported. In India, not many reports are available about the anthropometric and lipid profiles of women with PCOS. Therefore, we examined the blood sugar, lipid profile, obesity and adiposity measured anthropometric indicators (height, weight, waist and hip circumference (WC), body mass index (BMI), waist-hip ratio (WHR) and waist-to-height ratio (WHtR), skeletal muscle mass, percent total body fat and percent visceral fat) of 171 Indian women with PCOS who were attending a multi-disciplinary clinic in Mumbai, India. Overweight/obesity was common as 15.8% of women were overweight, 62% were obese. A large percentage of women had a higher amount of total percent body fat and some had high levels of visceral fat. WC, WHR, WHtR were above the desirable cut-off for a substantial percentage of women. Approximately, one-third of the women had low hemoglobin (33.7%), a considerable percentage had higher fasting (25.5%) and post-prandial blood sugars (14.3%). Approximately one-fourth had elevated total cholesterol (22%), triglycerides (20.7%), LDL cholesterol (33.6%) and low HDL cholesterol (36.2%). The present study provides evidence that diet and lifestyle play a crucial role in PCOS, and it is important to educate women with PCOS about adopting balanced wholesome diets and being physically active to improve their health.

Keywords: Cholesterol; Body Mass Index; Waist-Hip Ratio

Introduction

Polycystic ovarian syndrome (PCOS) affects about 8 to 13% of women [1]. In India, the prevalence has been estimated to vary from 8.1% to 21.27% [2,3]. A previous study by our group in urban Mumbai indicated that the prevalence was as high as 22.5% [4]. Ganie., *et al*. in 2019 have reported that in Indian women, the prevalence of PCOS could vary from 3.7 to 22.5 percent depending on the population studied and the diagnostic criteria used [5]. A systematic review and meta-analysis conducted by Sharma and co-workers among adolescent girls indicated a prevalence of 17.74% as per the Rotterdam criteria [6]. Vidya Bharathi and colleagues estimated from a cross-sectional study in Tamil Nadu, southern India that the odds of urban women having PCOS were slightly higher (0.1 times) as compared to rural women [7].

PCOS has 'a complicated interwoven pathophysiology' the signs and symptoms reflecting the androgen excess and ovulatory dysfunction that results in distressing features besides hirsutism, infertility in addition to menstrual irregularities [8]. This endocrinopathy is associated with a higher than desirable body mass index (BMI), adiposity, metabolic dysfunction including impaired glucose metabolism, hyperinsulinemia and insulin resistance. However, abdominal adiposity is one of the important clinical markers of insulin resistance irrespective of body mass index [9,10]. Risk of dyslipidemia particularly high triglycerides, low HDL cholesterol, elevated blood pressure is higher for women with PCOS, making them vulnerable to type 2 diabetes mellitus and cardiometabolic disorders.

Impaired glucose tolerance has been reported to be present in anywhere from one-fourth to one-third of PCOS women and type 2 diabetes has been reported to be prevalent in anywhere from 4% to 10% [11,12]. Most of these studies have been reported from other countries and there are only a few studies on Indian women with PCOS. Misra., *et al*. in 2004 reported that Indian women with PCOS have higher fasting insulin levels and greater insulin resistance than white women [13].

In clinical settings, it is important to pay attention to those biochemical risk factors that are routinely investigated for example- abnormal lipid levels and their correlates. High triglycerides in itself as well as the TG/HDL ratio are indicative of insulin resistance, cardiometabolic dysfunction and development of type 2 diabetes mellitus (DM). They have been found to be positively correlated with the occurrence of prediabetes and diabetes [14]. Thus, it is important to have a comprehensive profile of all risk factors for women with PCOS. We examined the blood sugar, lipid profile, obesity and adiposity, measured anthropometric indicators and bioelectric impedance of Indian women with PCOS who were attending a multi-disciplinary clinic in Mumbai, India.

Materials and Methods

Study design and sample

This was a retrospective study conducted on women with confirmed polycystic ovarian syndrome who were attending the special multi-disciplinary PCOS health clinic conducted by the Indian Council of Medical Research- National Institute of Research in Reproduction (ICMR-NIRRH) at Parel, Mumbai. Baseline data was available for 171 women who had attended the clinic between 2016 to 2020 before the lockdown in March 2020.

Data collection

All data including anthropometric measurements, body composition measurements, biochemical markers were taken from the case record forms maintained in the Institute's clinic. These data were entered into SPSS (version 19.0).

Anthropometric measurements

Height was measured using a stadiometer in centimetres to the nearest 0.1 cm. Weight was measured using a digital weighing scale in kilograms, to the nearest 100g. Body mass index (BMI) was calculated and the women were categorized as underweight (<18.50), normal (18.5-22.99), overweight (23- 24.9), pre-obese (25-29.9), obese (≥30), obese type 1 (30-40), obese type 2 (40.1-50) and obese type 3 (>50) using the cut-off points for Asians [15]. Waist circumference (WC) was measured in centimetres (± 0.1 cm) midway between the lower costal margin and the iliac crest and a circumference ≥80 centimetres was used as an indicator of abdominal adiposity [16]. Hip circumference was measured at the maximum circumference over the buttocks, to the nearest 0.1 cm. The waist-to-hip ratio (WHR) was calculated and a WHR ≥0.80 was used as the cut-off to identify women with higher levels of abdominal fat [17]. In addition, waist to height ratio (WHtR) was calculated and the value of ≥0.50 as suggested by Ashwell and Hsieh was used as the optimal cut-off to identify women with abdominal adiposity [18].

Body composition

Body composition measurements including percent skeletal muscle mass, percent total body fat and percent visceral fat were measured using the Omron Karada scan HBF-701 body composition monitor. Cut-off values used for categorizing women as having normal or high amounts of body fat or visceral fat were based on the values given in the Omron Karada HBF-701 instruction manual. For percent body fat, the cut-off values were- <20% = low body fat, 20-29.9% = normal body fat, 30.0-34.9% = high body fat and >35% = very high body fat. For visceral fat the cut-off levels were 0.5-9.5 = normal, 10.0-14.5 = high and >15.0 = very high visceral fat.

Biochemical markers

Fasting and postprandial plasma glucose, lipid profile i.e. triglycerides, total cholesterol, lipoprotein (LDL), high-density lipoprotein (HDL) and hemoglobin were measured at the time of the patient's attendance at the clinic.

The measurements were carried out at a standard National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited laboratory. Total cholesterol was measured spectrophotometrically using cholesterol esterase peroxidase, triglycerides, low-density lipoprotein (LDL) and HDL were also measured. Fasting and post-prandial plasma and glucose fasting plasma were analyzed using spectrophotometry hexokinase.

Data analysis

The data was analyzed using Statistical Package for Social Science (SPSS) Statistics version 21.0. Descriptive statistics included means, standard deviations and percentages. Tests applied were Analysis of Variance (ANOVA), Student's t-test and Pearson's chi-square test. A p-value <0.05 was set to determine statistically significant differences.

Results

Profile of Women: Among the 171 participants, 4.1% were between 15-18 years of age, 39.2% were young adults between 19-25 years and the remaining 56.8 percent of women were above 26 years of age, with 39 years being the maximum age observed among these women (Table 1).

Measurements	Mean ± sd	Median	Minimum	Maximum
Anthropometric indices				
Age (years)	26.3 ± 4.8	27.0	15	39
Weight (kg)	63.3 ± 13.0	62.1	35.0	98.2
Height (cm)	153.8 ± 5.6	153.0	140.0	167.0
BMI (kg/m^2)	26.8 ± 4.9	26.5	16.4	39.7
Waist circumference	86.8 ± 13.5	86.0	50.0	153.0
Hip circumference	101.2 ± 10.9	100.0	73.0	149.0
Waist to hip ratio	0.86 ± 0.11	0.85	0.41	1.59
Waist to height ratio	0.56 ± 0.09	0.55	0.33	1.00
Biochemical measurements				
Hemoglobin (g/dl) (n = 166)	12.4 ± 1.2	12.7	7.6	16.2
Fasting blood sugar (mg/dl)(n = 169)	95.4 ± 14.1	94.0	73.0	188.0
Postprandial blood sugar (mg/dl) (n = 168)	109.8 ± 31.6	103.5	52.0	276.0
Total cholesterol (mg/dl) (n = 164)	176.8 ± 35.7	178.0	78.0	282.0
Triglycerides (mg/dl)	109.9 ± 58.1	96.0	29.0	373.0
HDL (mg/dl)	44.8 ± 18.4	42.0	25.0	236.0
LDL (mg/dl)	117.6 ± 30.8	117.5	31.0	210.0

Table 1: Mean values for Anthropometric Measurements and Lipid Profile of Women with PCOS (n = 171).

Anthropometric Indices and Body Composition: As per the WHO criteria for BMI for Asians, more than 75% of participants were overweight/obese; 38.6% of women were in the pre-obese category, 23.4% were in the obese type 1 category and 15% were overweight. Thus, very few women had a normal BMI [15]. Similarly, a very high percentage of women had circumference measurements or ratios above the recommended cut-offs. Two-thirds (63.7%) of the women had WC exceeding the cut-off value of 80 cm recommended by Misra., *et al*. and for 71.4% of women, the WHR was above 0.80 [16]. Also, 73.7% of women had a WHtR ≥0.5 [18]. The findings for all the anthropometric indicators showed that adiposity including abdominal adiposity was high for at least two-thirds of the women.

WC, WHR and WHtR were compared between the different BMI categories. The mean WC values for women who were in the pre-obese and obesity type 1 category were 89.3 ± 10.7 cm and 100.3 ± 9.8 cm, respectively. In comparison, significantly lower mean values were observed for underweight women (66.3 ± 11.9 cm) or overweight (79.6 ± 7.9 cm), and those with normal BMI (74.2 ± 6.7 cm) (F = 45.720, p = 0.000). Similarly, mean WHR was slightly but significantly higher (F = 4.966, p = 0.001) for the pre-obese and obese women (0.9 ± 0.1) for both, as compared to mean values of 0.8 ± 0.1 for the underweight, normal weight, and overweight women. Further, significant differences were seen in the mean WHtR between the BMI categories (F = 45.307, p = 0.000).

The percentage of women with WC >80 cm was only 8.8 among those with normal BMI, whereas none of the underweight women had a WC above this cut-off level. However, among women who were overweight (n = 27), 51.9% had a WC >80 cm. The percentages of women with WC>80 cm were even higher among the pre-obese category (89.4%), and type 1 obese (97.5%) categories. A similar trend was seen for WHtR. None of the underweight women had a WHtR exceeding 0.5, in contrast to all the women in the type 1 obesity group having a high WHtR. The percentages of women with WHtR> 0.5 were 38.2% among the normal BMI category, and 66.7% among those who were overweight, and 93.9% among those who were pre-obese.

A slightly different trend was observed for WHR, although the ratio was above 0.8 in a considerable percentage of women. Half of the underweight women (50%), had a WHR >0.8. In the other BMI categories, the percentage of women with a higher than desirable WHR was 61.8% among women with normal BMI, 59.3% in the overweight categories, and 80.3% and 90% in the pre-obese and type 1 obese categories, respectively.

Mean values for body weight, BMI, WC, and WHtR were significantly higher for women with WHR>0.8 than those with WHR<0.8 (Table 2). Similar trends were seen for women with normal (≤ 0.5) and higher than normal WHtR (>0.5).

Measurement	Waist to Hip Ratio		t,p	Waist to height ratio		t,p
	<0.80 n = 62	≥0.80 n = 109		≤0.50 n = 45	>0.50 n = 126	
Weight (kg)	55.2 ± 9.8	65.6 ± 12.9	-4.617, 0.000	50.8 ± 7.9	66.7 ± 12.0	-7.648,0.000
BMI (kg/m^2)	23.8 ± 3.6	27.6 ± 4.9	-4.571, 0.000	21.6 ± 2.9	28.2 ± 4.4	-8.642,0.000
Waist circumference	73.6 ± 8.3	90.6 ± 12.3	-7.996, 0.000	71.3 ± 6.2	91.1 ± 11.7	-9.912,0.000
Hip circumference	99.4 ± 12.9	101.8 ± 10.2	-1.201, 0.231	93.5 ± 11.9	103.4 ± 9.6	-5.211,0.000
Waist to Height ratio	0.5 ± 0.1	0.6 ± 0.1	-7.839,0.000	0.8 ± 0.1	0.9 ± 0.1	-6.369,0.000

Table 2: Mean Body weight, BMI, WC, HC and WHtR of women with WHR (<0.8 and >0.8) and WHtR (≤0.5 and >0.5).

Data on percent body fat and visceral fat as well as skeletal muscle mass were available for 168 women. Mean skeletal muscle mass was 23.8 ± 2.8%, mean percent total body fat was 35.0 ± 4.8% and the mean visceral fat was 8.4 ± 5.6. None of the participants had less than 20% body fat, with only 16.3% having a normal amount of percent body fat. Thus, most women had higher than desirable levels of body fat, 29.5% had body fat levels between 30.0-34.9%, but a little more than half of the participants (54.2%) had very high body fat exceeding 35%. The percentage of women with high visceral fat was relatively much lower, as 71.8% had normal visceral fat levels below 9.5. A little more than one-tenth, 14.7% had a high amount of visceral fat (10.0-14.5) and 13.5% had very high visceral fat (>15.0).

Comparison by BMI categories showed that there were significant differences in skeletal muscle mass (F = 5.577, p = 0.000), total percent body fat (F = 55.167, p = 0.000) and visceral fat (F = 72.722, p = 0.000). Skeletal muscle mass was highest for underweight women and decreased with increasing BMI. Total percent body fat and visceral fat were highest for women in the preobese Type 1 category.

All underweight women had normal levels of total body fat, however, among women with normal BMI, 42.4% had high levels of body fat, with three women having very high body fat exceeding 30%. In the overweight category, 51.9% had high body fat and 22.2% had very high levels of body fat. Thus, among overweight women, only 25.9% had normal levels of body fat. In the pre-obese and type 1 obese categories, all women had either high or very high levels of body fat, exceeding 35%.

Similar trends were observed for visceral fat. All the underweight women and those with normal BMI as well as those who were overweight had visceral body fat between 0.5 and 9.5. The percentage was slightly lower for women in the pre-obese category (88.9%), but none of those who were type 1 obese had visceral fat in this range. The percentage of women with visceral fat between 10 and 14.5% was 7.9% and 48.7% in the pre-obese and type 1 obese category and 51.3% of the type 1 obese women had higher amounts of visceral fat exceeding 15%.

A little less than a quarter of the participants with normal WC had normal body fat values, whereas 32.8% had a high amount of body fat and two-thirds (42.6%) of the women with normal WC had very high percent body fat. Among those with WC above 80cm, the majority of the participants (71.4%) had body fat above 35%, a little more than one-fourth had high percent body fat (30-34.9%) and only one participant had a normal value for percent body fat.

Mean levels of total body fat and visceral fat were significantly higher among women with a high WHR and WHtR (Table 3).

Biochemical measurements

One-third (33.7%) of the women were anemic, with hemoglobin (Hb) below 12 g/dl. Only one woman had Hb above 15g/dl. A considerable percentage of women (23.1%) had fasting blood glucose values between 100-125 mg/dL. Post-prandial blood glucose levels (values between 140-199 mg/dL) indicated that 11.9% of the women were pre-diabetic. Four women (2.4%) were diabetic as indicated by their fasting and postprandial blood glucose values.

Measurement	Waist-to-Hip Ratio		t,p	Waist-to-height ratio		t,p
	<0.80	≥0.80		≤0.50	>0.50	
Skeletal muscle (kg)	24.1 ± 1.7	23.7 ± 3.0	0.735, 0.463	25.3 ± 1.7	23.4 ± 2.9	3.717, 0.000
% Total body fat	33.1 ± 4.3	35.6 ± 4.8	-2.784, 0.006	30.4 ± 4.7	36.3 ± 3.9	-7.672, 0.000
Visceral fat	6.0 ± 5.3	9.1 ± 5.5	-2.997, 0.003	3.7 ± 2.0	9.7 ± 5.5	-6.210, 0.000

Table 3: Mean skeletal muscle, Percent total body fat and visceral fat of women with WHR (<0.8 and >0.8) and WHtR (≤0.5 and >0.5).

Some women had higher than normal levels of cholesterol and triglycerides, based on the ATP- III guidelines [19]. Although 78% of the women had normal total cholesterol values, 17.1% had borderline high values (200-239 mg/dL) and 4.9% had values ≥ 240 mg/dL. Triglyceride values in the range of 150-199 mg/dL were seen in 12.8% and 7.9% of women had levels between 200-499 mg/dl. Low HDL levels below 40 mg/dL were observed in 36.2% of the women and only 8.6% of women had values ≥ 60 mg/dL. Optimum levels of LDL (<100 mg/dL) were seen in 32.9% of women, and 33.5% had LDL levels between 110-129 mg/dL, 22.6% of the women had borderline high levels between 130-159 mg/dL, and 8.5% had high levels between 160-189 mg/dL.

Biochemical Parameters vis – à- vis BMI, and indicators of adiposity

Lipid levels were compared among BMI categories (Table 4). Differences were observed among the BMI categories for triglycerides and HDL, but not for total and LDL cholesterol. Mean triglyceride levels were higher in the higher BMI categories, whereas HDL levels were lower in the higher BMI categories. Women who were underweight, normal weight or overweight had higher HDL levels as compared to the participants who were obese.

The mean hemoglobin level was 12.4g/dl, varying from a minimum of 7.6 g/dL and a maximum of 16.2 g/dL. Sixty-five percent had normal hemoglobin values between 12 and 15 g/dL but 33.7% were anemic, as their hemoglobin was their hemoglobin values were below 12g/dL [20]. A higher percentage of women who were underweight and who were overweight, preobese and obese had Hb levels below 12 g/dl, compared to those with normal BMI. The percentage of women with elevated fasting blood sugar (>100 mg/dl) as well as postprandial blood sugar (>140 mg/dl) was approximately two times more than among women who were underweight or were in the normal BMI categories (Figures 1, 2).

Similarly, elevated triglyceride levels were seen in approximately one-fourth of the women who were overweight /pre-obese and about one-third who were obese. A higher percentage of the women with higher BMI had elevated cholesterol levels as compared to the normal BMI category. Almost half of the women who were overweight or pre-obese or obese had low HDL levels.

Further, comparisons were made between women with a normal waist-to-hip (WHR) ratio (≤0.80) and those with a higher WHR (>0.80). There was no significant difference between the two groups in the mean values for fasting blood sugar (t = 0.099m, p = 0.921) and postprandial blood sugar (t = -1.218, p = 0.225), total cholesterol (t = -1.446, p = 0.150), LDL cholesterol (t = 1.938, 0.054). However, mean triglycerides were significantly higher (t = -3.083, p = 0.002) among women with higher WHR (117.4 ± 59.9

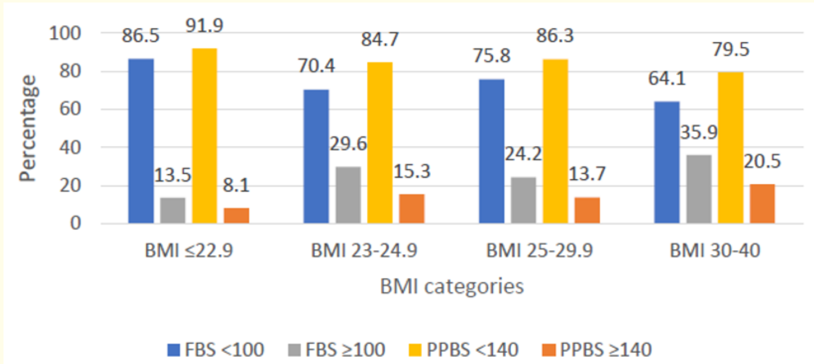

Figure 1: Percentage of women with normal and elevated fasting blood sugar and post prandial blood sugar levels in different BMI categories.

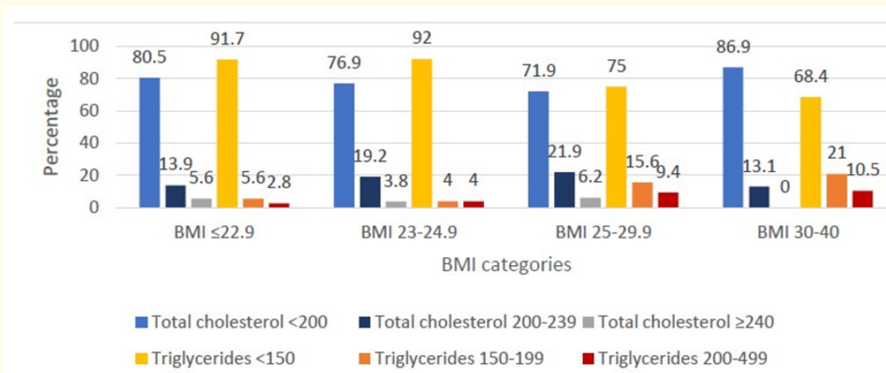

Figure 2: Percentage of women with normal and elevated total cholesterol and triglyceride levels in different BMI categories.

mg/dl) than women with normal WHR (85.1 ± 43.9 mg/dl). Women with normal WHR had a mean HDL value of 52.7 ± 32.3 mg/dl, which was significantly higher (t = 3.047, p = 0.003) than women with a WHR >0.80. Similar marked differences were observed between women with WHtR >0.50 and WHtR ≤ 0.50. The mean triglyceride level in the former group was 118.8 ± 58.9 mg/dl which was significantly higher (t = -3.863, p = 0.000) than the group with WHtR <0.50 (78.2 ± 42.5 mg/dl). HDL levels were 52.01 ± 12.0 mg/dl for women with normal WHtR compared to a mean value of 42.9 ± 19.4 mg/dl with higher WHtR, with the difference between the two groups being statistically significant (t = 2.651, p = 0.009).

Further, a much higher percentage of women with values above the normal cut-offs for the three anthropometric indices, WC, WHR and WHtR had elevated levels of fasting and post-prandial blood glucose levels, as well as lipid values, and low hemoglobin values (Table 5).

Discussion

The findings of the present study on urban women with PCOS who attended a multi-disciplinary specialty PCOS clinic showed that the majority of the women had high body mass index as per the WHO recommendations for Asians [15]. Approximately three-fourths of the women had a higher WHR and WHtR, and two-thirds had a high waist circumference. Although none of the underweight women had a WHtR >0.50, 38.2 percent of the women with normal BMI had a high WHtR, indicating that a substantial percentage of women with normal BMI are likely to be at risk for metabolic dysfunction. This clearly indicates that BMI alone does not reflect adiposity, particularly abdominal adiposity and it is important to use

Biochemical marker	BMI Categories (kg/m²)							F,p
	n	All women	<18.50	18.50-22.99	23.00-24.99	25.00-29.99	30.00-40.00	
Hemoglobin (g/dl)	166	12.2 ± 1.2[1] 7.6-16.2[2]	12.7 ± 1.2 11.7-14.4	12.2 ± 1.6 7.6-16.2	12.6 ± 0.9 10.7-13.8	12.5 ± 1.1 10.1-15.5	12.5 ± 15.4 7.8-15.1	0.608,0.657
Fasting blood sugar (g/dl)	169	95.5 ± 14.1 73.0-188.0	87.5 ± 10.1 78.0-101.0	92.1 ± 7.8 81.0-112.0	97.0 ± 20.7 63.0-188.0	94.7 ± 10.2 74.0-151.0	99.5 ± 17.9 73.0-188.0	1.725,0.147
Postprandial blood sugar (g/dl)	168	109.8 ± 31.6 52.0-276.0	99.3 ± 9.0 92.0-112.0	103.3 ± 23.8 67.0-179.0	108.4 ± 43.8 52.0-276.0	110.9 ± 209.4 57.0-214.0	115.4 ± 32.8 59.0-203.0	0.798,0.528
Total cholesterol (mg/dl)	164	176.8 ± 35.7 78.0-282.0	164.3 ± 30.4 142.0-199.0	174.7 ± 38.2 105.0-282.0	177.8 ± 37.8 110.0-276.0	181.6 ± 36.1 78.0-270.0	170.6 ± 32.2 114.0-244.0	0.694,0597
Triglycerides (mg/dl)	164	109.9 ± 58.1 29.0-373.0	73.0 ± 46.9 43.0-127.0	82.5 ± 42.9 32.0-226.0	101.9 ± 58.3 29.0-349.0	117.9 ± 58.3 29.0-349.0	128.6 ± 66.9 39.0-373.0	3.790,0.006
HDL (mg/dl)	163	44.8 ± 18.4 25.0-236.0	47.1 ± 5.1 44.2-53.0	51.4 ± 11.6 31.0-86.0	55.1 ± 38.3 34.0-236.0	40.5 ± 8.8 25.0-81.0	39.4 ± 8.6 26.0-64.0	5.258,0.001
LDL (mg/dl)	164	117.6 ± 30.8 31.0-210.0	105.1 ± 34.8 84.0-145.2	111.6 ± 30.7 64.0-197.0	115.3 ± 33.6 53.0-190.0	124.5 ± 31.3 31.0-210.0	113.7 ± 27.1 72.0-170.0	1.446.0.221

Table 4: Mean Values for Hemoglobin , Fasting and Postprandial Sugar, Cholesterol, Triglycerides, HDL and LDL by BMI Category.

[1]Mean ± sd, [2]Minimum-Maximum.

Measurements	Waist Circumference		Waist to Hip Ratio		Waist to Height Ratio	
	≤80 cm	>80 cm	≤0.80	>0.80	≤0.50	>0.50
Hemoglobin (<12g/dl)	36.0	27.6	37.5	28.0	34.1	29.5
Fasting blood sugar (>100 mg/dl)	80.6	71.0	79.6	72.5	82.2	71.8
Postprandial blood sugar (>140 mg.dl)	8.0	17.9	8.2	16.9	8.9	16.2
Total cholesterol (> 200 mg/dl)	19.7	23.3	22.5	81.8	23.8	21.7
Triglycerides (>150 mg/dl)	6.6	29.1	12.2	24.4	9.0	25.0
HDl (<40.0 mg/dl)	83.3	52.4	87.5	54.0	90.7	54.1
LDL (>100 mg/dl)	59.0	71.8	51.1	72.2	56.8	60.8

Table 5: Percentages of women with low hemoglobin, and elevated fasting and postprandial blood sugar and lipid levels in women with WC (>80cm), WHR (0.80) and WHtR (0.50).

these anthropometric indicators in addition to BMI while screening patients at entry, to enable appropriate interventions. Our findings are in line with previous reports in the literature. In an early study Cosar., *et al*. observed that women diagnosed as having PCOS according to the Rotterdam consensus criteria, had significantly higher waist-to-hip ratios than did women without PCOS [21]. Svendsen., *et al*. in 2008 and Karabulut., *et al*. in 2011 reported that women with PCOS are more likely to carry excess adiposity, particularly in the central region in contrast to BMI-matched controls [22,23]. Thatupadi and coworkers also observed that women with PCOS had higher mean values for BMI, larger waist and hip circumferences as well as waist-to-hip ratio [24]. Among women who had irregular menstruation, hyperandrogenism and polycystic ovaries, 95% had central obesity as well as higher BMI and large waist and hip circumferences.

In our study, we found that approximately 3/4ths of the women had a WHtR exceeding 0.5. The isolated reports by Kiranmayee., *et al*. in S. India and Abeer-Rasool., *et al*. in Srinagar exhibited similar trends for a very high percentage of women with PCOS having a high WHtR as compared to healthy women [25,26].

Misra., *et al*. in their consensus statement regarding WC, have proposed two levels of WC cut offs [16]: "Action level 1: Men: 78 cm, women: 72 cm. Any person with WC above these levels should avoid gaining weight and maintain physical activity to avoid acquiring cardiovascular risk factors. Action level 2: Men: 90 cm, women: 80 cm. Subject with WC above this should seek medical help so that obesity-related risk factors could be investigated and managed." As per these cut-offs, only 19 out of 171 women (11.11%) had a WC ≤72cm. Thus, the remaining 88.89% would have an increased risk of developing dyslipidemia, impaired fasting glucose or impaired glucose tolerance and to prevent this. Thus, the advice regarding lifestyle modifications should include increased physical activity as part of the treatment and management.

Because PCOS is a chronic endocrine and metabolic disorder, body composition is likely to change over time. This can impact the ability to lose fat and may increase the risk of developing comorbidities such as insulin resistance, diabetes, and cardiovascular disease [21,27]. Visceral fat is highly metabolically active and produces proinflammatory cytokines, which can lead to insulin resistance, hypertension, and dyslipidemia as well as severe metabolic risks like metabolic syndrome, cardiovascular diseases and malignancies [28,29]. In the present study, not a single participant had less than 20% body fat, with only 16.3% having a normal amount of body fat i.e., 20-29.99%. Almost one-third of the women (29.5%) had high values for body fat (30-34.99%) and it is of concern that more than half of the participants (54.2%) had very high percent total body fat (>35%). With reference to visceral fat, the majority had visceral fat between 0.5-9.5. However, 14.7% of the participants had high levels between 10.0-14.5 and another 13.5% had very high amount of visceral fat (levels >15), indicating that these 28.2% of the women would be at risk of developing metabolic complications.

Recently, in 2019 Misra and coworkers reported that body fat increased with increasing BMI, which was also observed in the present study [30]. Further, the levels of visceral fat were higher in obese women as compared to the normal or overweight women with PCOS. Jena., *et al*. noted that irrespective of their BMI, women with PCOS had high levels of visceral adiposity [31]. However, in the present study, high visceral adipose tissue was observed only among the pre-obese and type 1 obese women. Carmina., *et al*. conducted a study on women with PCOS, and reported that BMI was strongly and significantly correlated with total fat (r = 0.94), trunk fat (r = 0.93), and central abdominal fat (r = 0.89) [32]. The abdominal adiposity was associated with higher insulin levels and reduced insulin sensitivity. In the present study, we did not measure insulin levels and hence were not in a position to gauge, the percentage of women who may have had reduced insulin sensitivity. In an earlier study, Kalra and coinvestigators similarly observed in Indian women with PCOS that overweight and obese patients had higher visceral fat, and subcutaneous fat compared to normal-weight women [33]. Waist circumference was correlated with total fat (r = 0.91, P = 0.000), visceral fat (r = 0.76, P = 0.000), and subcutaneous fat volume (r = 0.88, P = 0.000), and insulin resistance was significantly associated with WC, total fat, and subcutaneous fat volumes, but not with BMI.

Our group in 2020 compared the biological age vis-à-vis chronological age in women with PCOS [34]. The biological age of our participants was approximately 12 years more than their mean chronological age. Biological age advancement was correlated with the underlying metabolic dysfunction and body fat, indicating that in women with PCOS, metabolic dysfunction and adiposity could advance their biological age, which is also a marker for progression to non-communicable diseases.

Hyperandrogenism seen in women with PCOS is associated with android fat accumulation. This type of upper body fat distribution is associated with metabolic complications like hyperinsulinemia, impaired glucose tolerance, diabetes mellitus, etc. [21]. Also, central obesity, which, has been reported to be more common in women with PCOS can lead to obesity-related complications. In women with PCOS, increased whole-body fat as compared to lean mass is likely, to result in differences in metabolic dysfunction [35-37]. Obesity itself is also associated with increased cardiometabolic risks [38]. Thus, the women in our study would likely be at risk of metabolic dysfunction, given the high percentage of women who had more than desirable amounts of total body fat.

In the present study, we measured hemoglobin, fasting and post-prandial blood sugar, and the lipid profile of the women. One-third of the women were anemic. Han., *et al*. reported that obese women with PCOS had slightly lower hemoglobin levels than did lean PCOS women [27]. The authors stated that this was probably due to changes in the hormonal levels. Aigner, Feldman and Datz stated that "iron deficiency and obesity do not merely represent the coincidence of two frequent conditions but are molecularly linked and mutually affect each other" [39]. They suggested that it is possible that in obese persons, risk of iron deficiency may be higher because duodenal iron absorption may be inhibited. In about one-third of persons with metabolic syndrome or non-alcoholic fatty liver disease, "dysmetabolic iron overload syndrome (DIOS)" is frequently encountered. Possibly changes in energy homeostasis may be linked to alterations in iron homeostasis. Aigner and colleagues reported that there are reports of obesity in women being linked to lower serum iron levels. More recently, Pande, Ranjan and Kratasyuk in 2019 stated that hepcidin which is a key peptide regulating iron metabolism, also links anemia and obesity [40]. They proposed that the possible mechanism is the role of leptin produced by adipose tissue. Leptin regulates hepcidin synthesis by adipocytes and is probably responsible for the poorer iron status. Also, hepcidin is an acute-phase response peptide and is known to downregulate iron absorption. Thus, the higher levels of hepcidin in obese individuals lead to the risk of anemia. These aspects need to be investigated in women with PCOS and the role of obesity being linked to anemia which is highly prevalent as such in India [41].

Several reports in the literature indicate dyslipidemia among women with PCOS and stated that the most frequent abnormalities were low HDL cholesterol, high triglycerides and high LDL cholesterol as well as total cholesterol in women with PCOS, with BMI being negatively associated with these lipid measurements [11,12,25,42]. In the present study also, we observed that mean HDL levels decreased with an increase in BMI. In an early study, Hollmann., *et al*. observed in young obese women who did not have PCOS that WHR was positively correlated with triglycerides, cholesterol/HDL-cholesterol-ratio, and inversely with HDL-cholesterol [43]. Similarly, we observed in our women that there was a significant difference in triglycerides (t = -3.083, p = 0.002) and HDL cholesterol (t = 3.047, p = 0.003) among those with normal and higher WHR values.

WHtR is another marker of abdominal adiposity. Miralles., *et al*. found that WHtR was significantly correlated with anthropometric measurements and biochemical markers, with a positive correlation between BMI, waist circumference and body fat percentage, as well as a positive correlation between LDL cholesterol as well as triglycerides [44]. Saghafi-Asl., *et al*. (showed that waist circumference in women with PCOS was significantly correlated with total cholesterol (r = 0.32, p = 0.015) and LDL cholesterol (r = 0.28; p = 0.030), WHtR was also significantly correlated with TC (r = 0.37; P = 0.004) and LDL (r = 0.33; P = 0.011) [45]. Along similar lines, in the present study, we observed a significant difference in triglycerides (t = -3.863, p = 0.000) and HDL cholesterol (t = 2.651, p = 0.009) among women with normal and higher WHtR. Higher levels of TC were seen in most women with borderline cut-offs in 18.4%, 78.3% and 17.5% of women with above-normal WC, WHR and WHtR values respectively. High levels of ≥240 mg/dl were also seen in a quarter of the participants irrespective of the cut-offs. Low HDL levels were seen in almost half of the participants with the majority having above-normal cut-offs. 47.6%, 46% and 55.9% had above normal WC, WHR and WHtR cut-offs respectively and 16.7%, 12.5% and 9.3% had normal WC, WHR and WHtR cut-offs respectively. Ganie., *et al*. also reported that North Indian women with PCOS had higher triglycerides and LDL cholesterol as well as higher levels of pro-inflammatory markers whereas the levels of anti-inflammatory markers were lower [5]. Above desirable cut-offs for LDL were seen in many women with higher cut-offs, and a considerable number of women with normal cut-offs had above normal values or high LDL levels. Results showed that low levels of HDL were more common compared to higher levels of TC, TG, and LDL, indicating that women with PCOS are at a higher risk of dyslipidemia especially those with above-normal WC, WHR and WHtR cut-offs. Also, a considerable proportion had elevated fasting and postprandial blood sugar levels. This along with low hemoglobin highlights the need to counsel women with PCOS intensively to effect appropriate changes in their diets and lifestyles.

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