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Insulin Resistance and Its Associated Risk Factors in Nigerian Women with Polycystic Ovary Syndrome

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Abstract

Background: The etiology of polycystic ovary syndrome (PCOS) is not completely understood; however one condition that correlates closely with the pathogenesis of PCOS is insulin resistance (IR). The objective of this study was to determine the prevalence of insulin resistance (IR) and the association of such abnormality with potential risk factors in women with PCOS. **Method:** 116 women with confirmed PCOS attending a reproductive clinic at the University of Benin Teaching Hospital in Benin City were studied. IR was determined by homeostatic model assessment (HOMA) ≥ 2 and pre-diabetes by fasting plasma glucose between 110 and 125 mg/dl and/or plasma glucose value between 140 and 200 mg/dl at 2 hours during an oral glucose tolerance test (OGTT) after ingestion of 75 g oral glucose load. **Results:** Forty-two women were insulin resistant among the 116 women with PCOS. The prevalence of IR was 36.2% (95% CI 26.6 - 46.2). The prevalence of impaired fasting glucose (IFG) showed 1.7% (95% CI 0.97 - 2.03), impaired glucose tolerance (IGT) was 2.6% (95% CI 1.97 - 3.03) and diabetes mellitus (DM) was 1.7% (95% CI 0.97 - 2.03) in the 116 PCOS women. Of these 42 insulin resistant PCOS women, 23.8% (n = 10) were obese and 40.5% (n = 17) were overweight. Multivariate analysis revealed that total cholesterol (OR, 1.07; 95% CI, 1.04 - 1.10), triglycerides (OR, 1.08; 95% CI, 1.04 - 1.13) and LDL-cholesterol (OR, 1.08; 95% CI, 1.04 - 1.12) were statistically significant independent risk factors for IR. **Conclusion:** The prevalence of IR was high in women with PCOS, and there was a significant association between IR, obesity, and dyslipidemia. However, the prevalence rates of impaired glucose tolerance and DM were low in women with PCOS compared to other studies. Since women with PCOS are at risk of IR and dyslipidemia, early screening, detection, intervention, and lifestyle modification would ameliorate the financial burden of DM and cardiovascular disease (CVD).

Keywords

Impaired Glucose Tolerance, Insulin Resistance, Nigerian Women, Polycystic Ovary Syndrome, Risk Factors

1. Introduction

Polycystic ovary syndrome (PCOS) is the most common endocrine disorder affecting women in childbearing age. It is a heterogeneous disorder whose pathogenesis is not well understood despite evidence of complex interaction with genetic, behavioral and environmental factors that contribute to its occurrence [1]. The manifestations of PCOS are not confined to the gynecological sphere. Women afflicted by this disorder show an increased prevalence of several co-morbidities, including obesity, dyslipidemia, hypertension, metabolic syndrome (MS), and type 2 diabetes mellitus (T2DM) in comparison with women without PCOS, and these features underlie the greater risk of developing cardiovascular disease (CVD) [2]. However, one condition that correlates closely with the pathogenesis of PCOS is insulin resistance, which is present in 50% - 75% of women with PCOS [3]. Insulin resistance and subsequent compensatory hyperinsulinemia which are closely related to the pathogenicity and co-morbidities of PCOS can be exacerbated by the coexistence of obesity which affects approximately 50% of PCOS women [4]. The prevalence rates of IR reported among US women with PCOS range from 44% to 70% [3] which are significantly higher than the rates reported among Iranian, Thai, and Vietnamese PCOS women [5] [6] [7]. Reyes-Munoz *et al.* (2016) [8], reported IR prevalence of 60.2% among infertile Mexican women with PCOS, a rate that was higher in overweight and obese women than in normal-weight women. Some studies have reported independent risk factors associated with IR in PCOS women to include age, BMI, waist circumference (WC), waist-to-hip ratio (WHR), the presence of acanthosis nigricans, dyslipidemia, and obesity [6] [7] [8]. Wanderley *et al.* (2018) [9] however, reported lipid accumulation product (LAP) and arterial hypertension (AH) as additional risk factors besides WC, BMI, and dyslipidemia in a high proportion of patients in their study. Considering that the prevalence rate of PCOS among Nigerian women is as high as 27.6% [10] and that no such study has been conducted to the best of our knowledge in this region, there is the need to provide data on the prevalence of IR in our population for improved clinical decision making. The present study aims at determining the prevalence of IR and the association of such abnormalities with potential risk factors in women with PCOS.

2. Methods

A sample of women attending the infertility clinics at the University of Benin Teaching Hospital (UBTH) and the Women's Health and Action Research Cen-

tre (WHARC) in Benin City, Nigeria between April 1, 2009, and November 30, 2010, formed the subject of the study. Among the women, 116 (aged 18 - 45 years) were diagnosed with PCOS according to the 2003 Rotterdam criteria [10]. After fully informed consent was obtained from the women, a pre-prepared standard proforma was used to obtain data on their age, clinical and medical history, anthropometric and blood pressure measurements, and hirsutism/skin manifestations. The detailed method of clinical examination has been published elsewhere [10].

Glucose tolerance was evaluated using a 75 g oral glucose tolerance test (OGTT). After an overnight fast of at least 12 hours, the first venous blood sample was collected at 08:30 hour from the antecubital vein, while the second sample was collected two hours after 75 g oral glucose loading. The first blood sample was analyzed for baseline metabolic profiles, namely, fasting plasma glucose (FPG), total cholesterol, triglycerides (TG), high density lipoprotein-cholesterol (HDL-C), low density lipoprotein-cholesterol (LDL-C), and hormonal profile fasting insulin (FI). The second blood sample was analyzed for plasma glucose.

Insulin resistance was diagnosed using three indirect methods, namely, fasting insulin in excess of 25 μU/ml, the fasting glucose to fasting insulin ratio lower than 4.5 [11], and the homeostasis model assessment-insulin resistance (HOMA-IR) calculated using Matthew's formula ≥ 2 [12] [13].

The abnormal glucose metabolism was classified according to the World Health Organization (WHO) criteria [14] as follows: 1) Impaired fasting glucose (IFG) levels ≥ 110 mg/dl and <126 mg/dl (6.1 - 6.9 mmol/l); 2) Impaired glucose tolerance (IGT) levels, that is, 2-hr plasma glucose ≥ 140 and <200 mg/dl (7.8 - 11.1 mmol/l); and 3) Type 2 diabetes mellitus (T2DM), that is, FPG ≥ 126 mg/dl or 2-hr plasma glucose ≥ 200 mg/dl.

Dyslipidemia was defined as total cholesterol ≥ 200 mg/dl, triglycerides ≥ 150 mg/dl, HDL-C < 50 mg/dl, or LDL-C ≥ 160 mg/dl, according to National Cholesterol Education Program Adult Treatment Panel (NCEP ATP) III, 2002 report [6] [15]. According to the definition recommended by the International Diabetes Federation (IDF), someone has metabolic syndrome if he/she has a raised blood pressure: a systolic blood pressure ≥ 130 mmHg or a diastolic blood pressure ≥ 85 mmHg or treatment of previously diagnosed hypertension [16].

Obesity was assessed by estimating body mass index (BMI, weight/height^2, kilogram per m^2). The BMI categories include underweight < 18.5; normal weight 18.5 - 24.9; overweight 25 - 29.9; and obesity ≥ 30.0 [14].

Plasma glucose levels were assayed using the standard glucose oxidase method, serum total cholesterol and triglycerides were assayed using the enzymatic method, and serum HDL-C levels were assayed using the precipitant method. All methods were adapted for use in the CHEMWELL autoanalyzer (Model 2902), AWARENESS TECHNOLOGY, Inc. Palm City, FL.USA. All kits for the assay were commercially available kits from RANDOX, USA. Methods for hormone analysis were described in a previous study [10].

Data analysis: Statistical analysis was performed using SPSS version 22 for Windows (SPSS Inc., Chicago, IL, USA). The normality of distribution of all continuous variables was checked using the Kolmogorov-Smirnov test. Data were presented in mean and standard deviation (SD), number (n) and percent (%), or odds ratios (ORs) and 95% confidence intervals (CI), as appropriate. Descriptive statistics were generated to enable comparisons between groups. Student t-test was used to compare HOMA-IR categorical data. Multivariate logistic regression analysis was performed to identify the significant potential risk factors for IR. Hosmer and Lemeshow test was used to check for the goodness of fit of the model. A Statistical significance was considered to exist when P-value was <0.05.

3. Ethical Consideration

The Ethics and Research Committee of the UBTH approved the study proposal and issued the clearance certificate (ADM/E.22 A/VOL.VII/174). Fully informed consent was obtained from all women who participated in the study. They were assured of the confidentiality of information obtained, and that the results will be used for research only and not for any other purpose.

4. Results

A total of 116 Nigerian women with PCOS who formed the subject of this study were categorized according to BMI, with normal-weight 41 (35.3%), overweight 54 (46.6), and obese 21 (18.1). Of these 116 women, 42 (36.2%) were diagnosed with insulin resistance (HOMA-IR ≥ 2), while 74 (63.8%) were not insulin resistant. The 42 insulin resistant women were also categorized according to BMI and it revealed that 15 (35.7%) women have normal-weight, 17 (40.5%) women are overweight, and 10 (23.8%) women are obese.

The age, anthropometric, blood pressure and biochemical characteristics of the 116 PCOS women of reproductive age are shown in Table 1. The mean age was 32.05 ± 5.36 years, mean BMI was 26.77 ± 3.85 kg/m^2, mean arterial blood pressure (MABP), 91.29 ± 10.94 mmHg, mean fasting insulin, 10.69 ± 11.26 μU/ml, mean fasting plasma glucose to fasting insulin ratio was 18.34 ± 25.03 mg/μU, mean HOMA-IR was 2.21 ± 2.46 and mean TT was 1.34 ± 1.45 ng/ml. From the mean age and BMI, the 116 PCOS women are relatively young and overweight.

Table 2 compares the characteristics of the insulin resistant (HOMA-IR ≥ 2) and the non-insulin resistant women in the groups against some independent parameters. The mean FPG showed a highly statistically significant increase (P = 0.001), and likewise the mean of 2-hour post-OGTT glucose and FI (P < 0.001) when compared to non-insulin resistant women, whereas the mean FPG:FI ratio showed a highly statistically significant decrease (P < 0.001) compared to the non-insulin resistant group. Moreover, the mean levels of total cholesterol, triglycerides, LDL-C, TT, and LH:FSH ratio were elevated but not statistically sig-

nificant when compared to the non-insulin resistant group. The mean HDL-C levels did not differ between each group. The greater abnormalities were found in glucose and lipid metabolism among women with IR than women without IR, which was expected.

Table 3 shows the prevalence of IR was 36.2% (n = 42) among the 116 PCOS women. Abnormal carbohydrate metabolism also showed the following: two (1.7%) women had IFG levels (≥110 mg/dl), five (4.3%) women had abnormal 2-hour glucose concentration (≥140 mg/dl) in the OGTT, three with IGT (2.6%) and two with DM (1.7%). Hyperinsulinemia was observed in nine (7.8%) women.

The multivariate logistic regression analysis shown in Table 4 indicates that the independent risk factors for IR include, total cholesterol (OR, 1.07; 95% CI, 1.04 - 1.10), triglycerides (OR, 1.08; 95% CI, 1.04 - 1.13), LDL-C (OR, 1.08; 95% CI, 1.04 - 1.12), FPG (OR, 1.11; 95% CI, 1.06 - 1.16) and 2-hour OGTT (OR, 1.29; 95% CI, 1.24 - 1.33). However, age, BMI, SBP, DBP were not significantly elevated and HDL-C was not significantly reduced. The multivariate logistic regression analysis in Table 5 predicts a statistically significant association of obesity with risk factors of IR and include age, SBP, DBP, total cholesterol, triglycerides, LDL-C, FPG, and 2-hour OGTT. There were a relative reduction of HDL-C levels in obese women (OR, 0.96; 95% CI, 0.89 - 1.03) and overweight women (OR, 0.98; 95% CI, 0.93 - 1.04) compared to normal-weight women, but this difference was not significant (P = 0.240 and P = 0.506 respectively). The Hosmer and Lemeshow test indicated that the model was fit (P = 0.953).

Table 1. Characteristics of the 116 Nigerian women with polycystic ovary syndrome.

Characteristics	Mean ± SD
Age (years)	32.05 ± 5.36
Height (m)	1.62 ± 0.06
Weight (Kg)	70.51 ± 12.0
BMI (Kg/m^2)	26.77 ± 3.85
SBP (mmHg)	119.22 ± 13.52
DBP (mmHg)	77.33 ± 11.06
MBP (mmHg)	116.73 ± 14.18
MABP (mmHg)	91.29 ± 10.94
FPG (mg/dl)	81.54 ± 14.82
2-hour post-OGTT glucose (mg/dl)	97.35 ± 26.81
FI (μU/ml)	10.69 ± 11.26
FPG:FI	18.34 ± 25.03
HOMA-IR	2.21 ± 2.46
Total Cholesterol (mg/dl)	171.45 ± 34.11
Triglycerides (mg/dl)	80.55 ± 29.67
HDL-C (mg/dl)	48.99 ± 15.72
LDL-C (mg/dl)	106.36 ± 33.04

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TT (ng/ml)	1.34 ± 1.45
LH:FSH	2.88 ± 2.73
FSH (IU/L)	7.97 ± 4.20
LH (IU/L)	19.10 ± 16.11

Values are the mean ± SD. Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FI, fasting insulin; FPG, fasting plasma glucose; FPG:FI, fasting plasma glucose to fasting insulin ratio; FSH, follicle stimulating hormone; HOMA-IR, homeostatic model assessment-insulin resistance; HDL-C, high density lipoprotein-cholesterol; kg/m^2, kilogram per meter squared; LDL-C, low density lipoprotein-cholesterol; LH, luteinizing hormone; LH:FSH, luteinizing hormone to follicle stimulating hormone ratio; MABP, mean arterial blood pressure; MBP, mean blood pressure; OGTT, oral glucose tolerance test; SBP, systolic blood pressure; TT, total testosterone.

Table 2. Comparison of the characteristics of 116 PCOS subjects with respect to their homeostasis model assessment of insulin resistance (HOMA-IR) using t-test.

Risk factors	Non-insulin resistant (HOMA-IR < 2), n = 74	Insulin-resistant (HOMA-IR ≥ 2), n = 42	P-value
Age (years)	32.15 ± 5.23	31.88 ± 5.65	0.797
Height (m)	1.62 ± 0.06	1.63 ± 0.07	0.188
Weight (Kg)	69.34 ± 10.96	72.58 ± 13.54	0.163
BMI (kg/m^2)	26.54 ± 3.77	27.16 ± 4.01	0.407
SBP (mmHg)	118.11 ± 14.68	121.19 ± 11.09	0.240
DBP (mmHg)	76.62 ± 11.26	78.57 ± 10.72	0.364
MBP (mmHg)	115.45 ± 14.56	118.97 ± 13.36	0.201
MABP (mmHg)	90.45 ± 11.47	92.78 ± 9.90	0.273
FPG (mg/dl)	78.22 ± 10.85	87.4 ± 18.75	0.001**
2-hour post-OGTT glucose (mg/dl)	87.77 ± 12.13	114.24 ± 36.00	<0.001**
FI (μU/ml)	5.04 ± 2.58	20.65 ± 13.59	<0.001**
FPG:FI (mg/μU)	25.42 ± 28.86	5.87 ± 4.87	<0.001**
Total cholesterol (mg/dl)	167.07 ± 28.41	179.17 ± 41.60	0.066
Triglycerides (mg/dl)	77.59 ± 26.81	85.76 ± 33.85	0.155
HDL-C (mg/dl)	48.14 ± 12.62	50.5 ± 20.14	0.438
LDL-C (mg/dl)	103.45 ± 28.00	111.5 ± 40.30	0.208
TT (ng/ml)	1.28 ± 1.09	1.45 ± 1.94	0.528
LH:FSH	2.75 ± 2.49	3.11 ± 3.13	0.498
FSH (IU/l)	7.88 ± 4.14	8.12 ± 4.36	0.774
LH (IU/l)	17.68 ± 13.57	21.59 ± 19.75	0.211

**P < 0.01 was highly significant; *P < 0.05 was significant; Values are the mean ± SD. Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FI, fasting insulin; FPG, fasting plasma glucose; FPG:FI, fasting plasma glucose to fasting insulin ratio; FSH, follicle stimulating hormone; HOMA-IR, homeostatic model assessment-insulin resistance; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; LH, luteinizing hormone; LH:FSH, luteinizing hormone to follicle stimulating hormone ratio; MABP, mean arterial blood pressure; MBP, mean blood pressure; OGTT, oral glucose tolerance test; SBP, systolic blood pressure; TT, total testosterone.

Table 3. Prevalence of insulin resistance and abnormal carbohydrate metabolism in 116 Nigerian women with polycystic ovary syndrome.

Characteristics	N	% (95% CI)
Insulin resistance (HOMA-IR ≥ 2)	42	36.2 (26.6 - 46.2)
Impaired fasting glucose	2	1.7 (0.97 - 2.03)
Impaired glucose tolerance	3	2.6 (1.97 - 3.03)
DM	2	1.7 (0.97 - 2.03)
Hyperinsulinemia (FI ≥ 25 μU/ml)	9	7.8 (6.82 - 8.78)

Abbreviations: 95% CI, 95 percent confidence intervals; DM, diabetes mellitus; FI, fasting insulin; HOMA-IR, homeostatic model assessment-insulin resistance.

Table 4. Multivariate logistic regression analysis for risk factors of IR in women with PCOS.

Variables	HOMA-IR	OR (95% CI)	P-value
Age (years)	≥2 (n = 42)	0.99 (0.92 - 1.06)	0.683
	<2 (n = 74)	1	
Height (m)	≥2 (n = 42)	1.01 (0.98 - 1.04)	0.545
	<2 (n = 74)	1	
Weight (kg)	≥2 (n = 42)	1.09 (0.98 - 1.21)	<0.001
	<2 (n = 74)	1	
BMI (kg/m^2)	≥2 (n = 42)	1.04 (0.88 - 1.24)	<0.001
	<2 (n = 74)	1	
SBP (mmHg)	≥2 (n = 42)	1.023 (0.99 - 1.06)	0.195
	<2 (n = 74)	1	
DBP (mmHg)	≥2 (n = 42)	1.019 (0.98 - 1.06)	0.383
	<2 (n = 74)	1	
MBP (mmHg)	≥2 (n = 42)	0.96 (0.91 - 1.02)	0.175
	<2 (n = 74)	1	
MABP (mmHg)	≥2 (n = 42)	0.99 (0.89 - 1.10)	0.839
	<2 (n = 74)	1	
Total cholesterol (mg/dl)	≥2 (n = 42)	1.07 (1.04 - 1.10)	<0.001
	<2 (n = 74)	1	
Triglycerides (mg/dl)	≥2 (n = 42)	1.08 (1.04 - 1.13)	<0.001
	<2 (n = 74)	1	
HDL-C (mg/dl)	≥2 (n = 42)	1.05 (1.00 - 1.11)	0.070
	<2 (n = 74)	1	
LDL-C (mg/dl)	≥2 (n = 42)	1.08 (1.04 - 1.12)	<0.001
	<2 (n = 74)	1	
FPG (mg/dl)	≥2 (n = 42)	1.11 (1.06 - 1.16)	<0.001
	<2 (n = 74)	1	
2-hour post-OGTT (mg/dl)	≥2 (n = 42)	1.29 (1.24 - 1.33)	<0.001
	<2 (n = 74)	1	
HOMA-IR	≥2 (n = 42)	28.33 (19.34 - 41.48)	<0.001
	<2 (n = 74)	1	

OR, odds ratio; 95% CI, 95 percent confidence intervals. P < 0.05 was significant. Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HOMA-IR, homeostatic model assessment-insulin resistance; HDL-C, high density lipoprotein-cholesterol; kg/m^2, kilogram per meter squared; LDL-C, low density lipoprotein-cholesterol; MABP, mean arterial blood pressure; MBP, mean blood pressure; OGTT, oral glucose tolerance test; SBP, systolic blood pressure.

Table 5. Multivariate logistic regression analysis of PCOS women with IR according to the BMI categories.

Variables	BMI Categories	OR (95% CI)	P-value
Age (years)	Obese	1.21 (1.10 - 1.32)	<0.001
	Overweight	1.13 (1.05 - 1.21)	0.001
	Normal-weight	1	
Height (m)	Obese	1.01 (0.97 - 1.05)	0.604
	Overweight	1.01 (0.97 - 1.04)	0.722
	Normal-weight	1	
Weight (kg)	Obese	1.54 (1.35 - 1.75)	<0.001
	Overweight	1.18 (1.05 - 1.33)	0.008
	Normal-weight	1	
BMI (kg/m^2)	Obese	1.39 (1.14 - 1.71)	0.001
	Overweight	1.18 (0.97 - 1.43)	0.097
	Normal-weight	1	
SBP (mmHg)	Obese	1.12 (1.07 - 1.17)	<0.001
	Overweight	1.08 (1.04 - 1.12)	<0.001
	Normal-weight	1	
DBP (mmHg)	Obese	1.17 (1.10 - 1.24)	<0.001
	Overweight	1.09 (1.04 - 1.14)	<0.001
	Normal-weight	1	
MBP (mmHg)	Obese	1.05 (0.97 - 1.13)	0.266
	Overweight	1.00 (0.93 - 1.07)	0.987
	Normal-weight	1	
MABP (mmHg)	Obese	1.11 (0.98 - 1.25)	0.098
	Overweight	1.04 (0.95 - 1.14)	0.377
	Normal-weight	1	
Total cholesterol (mg/dl)	Obese	1.08 (1.03 - 1.12)	<0.001
	Overweight	1.07 (1.04 - 1.11)	<0.001
	Normal-weight	1	
Triglycerides (mg/dl)	Obese	1.34 (1.27 - 1.42)	<0.001
	Overweight	1.05 (1.00 - 1.10)	0.054
	Normal-weight	1	
HDL-C (mg/dl)	Obese	0.96 (0.89 - 1.03)	0.240
	Overweight	0.98 (0.93 - 1.04)	0.506
	Normal-weight	1	
LDL-C (mg/dl)	Obese	1.10 (1.04 - 1.15)	0.001
	Overweight	1.12 (1.08 - 1.17)	<0.001
	Normal-weight	1	
TT (ng/ml)	Obese	1.01 (0.22 - 4.47)	1.000
	Overweight	1.14 (0.34 - 3.80)	0.827
	Normal-weight	1	
LH (IU/l)	Obese	0.63 (0.47 - 0.84)	0.001
	Overweight	0.98 (0.74 - 1.30)	0.885
	Normal-weight	1	
LH:FSH	Obese	0.79 (0.29 - 2.10)	0.631
	Overweight	1.10 (0.40 - 3.05)	0.857
	Normal-weight	1	
FPG (mg/dl)	Obese	1.15 (1.08 - 1.21)	<0.001
	Overweight	1.05 (1.00 - 1.10)	0.055
	Normal-weight	1	

Continued

2-hour post-OGTT (mg/dl)	Obese	1.22 (1.16 - 1.29)	<0.001
	Overweight	1.06 (1.02 - 1.11)	0.006
	Normal-weight	1	
HOMA-IR	Obese	2.41 (1.42 - 4.09)	0.001
	Overweight	1.29 (0.86 - 1.94)	0.210
	Normal-weight	1	

OR, odds ratio; 95% CI, 95 percent confidence intervals. P < 0.05 was significant. Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HOMA-IR, homeostatic model assessment-insulin resistance; HDL-C, high density lipoprotein-cholesterol; kg/m^2, kilogram per meter squared; LDL-C, low density lipoprotein-cholesterol; LH, luteinizing hormone; LH:FSH, luteinizing hormone to follicle stimulating hormone ratio; MABP, mean arterial blood pressure; MBP, mean blood pressure; OGTT, oral glucose tolerance test; SBP, systolic blood pressure; TT, total testosterone.

5. Discussion

This study was undertaken to establish the prevalence of insulin resistance among infertile women with PCOS in our region and to determine the risk factors associated with IR in PCOS women. This is the first study on the prevalence of insulin resistance in Nigerian women with PCOS to the best of our knowledge. The etiology of IR in women with PCOS, although intensively studied, is not entirely clear. The mechanisms involve a unique disorder of insulin action secondary to decreased insulin receptor signaling, likely caused by serine hyperphosphorylation of the receptor and of the insulin receptor substrate 1 [3]. The various techniques used for the diagnosis of IR include FPG, OGTT, glucose/insulin ratio, HOMA-IR, quantitative insulin sensitivity check index (QUICKI), and the gold standard which is the hyperinsulinemic-euglycemic clamp [3] [17] [18]. However, Wanderley *et al.* (2018) [9], analyzed the frequency of IR in Portuguese PCOS women using four of the indirect methods and reported no statistical difference among the four methods with regards to the frequency of IR. In this study, IR was determined using the HOMA-IR technique and the prevalence rate obtained among infertile Nigerian PCOS women was 36.2%. Several studies have reported higher prevalence rates of IR ranging from 44% to 70% among PCOS women in the US, 60.2% in Mexican women and 50.04% in Portuguese women [3] [8] [9] when compared to this study. However, lower prevalence rates were reported in Iranian (24.3%) and Thai (20.0%) women [5] [6] than observed in this study. The great variability observed in the prevalence rates might be attributable to the diagnostic criteria used in PCOS, different PCOS phenotypes, ethnic differences in insulin action, environmental factors such as diet, or the method used in identifying IR [3]. Some of these factors might have contributed significantly to the prevalence of IR in our region.

The prevalence of IGT and DM found in this study was low in contrast to that reported among US women with PCOS which ranged from 23% and 35% for IGT and between 4% and 10% for DM [19] [20] [21]. The prevalence rates reported in Thai (13.6%) [6], Australia (15.6%) [22], the Mediterranean region (15.7%) [23], Hispanics (22.1%) [8] and China (20.5%) [24] were still higher than the findings in this study. These different findings are suggestive of the ef-

fects of environmental factors and ethnicity, as also observed in the prevalence rates reported among Korean PCOS women [25].

Findings from PCOS women in this study demonstrated the presence of IR across the BMI categories, with the average frequency of 35.7% found in normal-weight, 40.5% found in overweight and 23.8% found in obese women. However, this was not consistent with the report of Wanderley *et al.*, 2018 [9] which showed the average frequency of IR as 20.31% in normal-weight, 50% in overweight and 76.59% in obese women. Other studies have observed that in the presence of obesity, IR frequency and magnitude increases [1] [4] [26]. In the present study, the findings showed that women are overweight, and the overweight category had the highest IR frequency. Moreover, there was a significant association of IR with obesity and dyslipidemia which is consistent with other reports [7] [9], and the association of IR with total cholesterol, triglycerides, and LDL-C reflected the effect of dyslipidemia for PCOS women, which might be suggestive of cardiovascular risk. Furthermore, the levels of FPG and 2-hour OGTT glucose are also adequate risk factors for IR in PCOS women in our region, especially in the presence of obesity. Some studies [27] suggested that IR could contribute to dyslipidemia frequently observed in PCOS women through various mechanisms, thus corroborating the findings in this study.

Some limitations in this study are worth mentioning and include the method used in the diagnosis of IR. Whereas the gold standard is the hyperinsulinemic-euglycemic clamp, it is quite elaborate in clinical practice. Nevertheless, the HOMA-IR which is an indirect method used in this study has been reported to have a good correlation with clamp technique [28]. Results obtained in this study included only PCOS women with infertility, therefore the outcomes are not generalizable to PCOS women without infertility. Additionally, this was not a population-based sample, as such further research is needed in this regard. However, findings in this study cannot be ignored as it has shown the prevalence of IR and its significant association with obesity and dyslipidemia in this region. A further study to compare IR among age-matched and BMI-matched non-PCOS women and those with PCOS would be necessary.

6. Conclusion

In conclusion, the findings obtained in the present study indicate that women with PCOS and IR in our population are associated with risk factors like obesity and dyslipidemia as observed in other regions, and are equally prone to cardiovascular risks. However, the prevalence of IGT was found to be low compared to other countries. Therefore, early detection, treatment, and appropriate lifestyle modifications could improve fertility, quality of life, and reduce the risk of PCOS long term complications.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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