OPEN ACCESS

GAVIN PUBLISHERS

Food & Nutrition Journal

Research Article

Toffoli-Ribeiro C, et al. Food Nutr J 5: 221.
DOI: 10.29011/2575-7091.100121

Correlations between Measurements of Body Adiposity and Metabolic Variables in Patients with Polycystic Ovarian Syndrome: A Case-Control Study

Camila Toffoli-Ribeiro[1*], Catarina Mendes Silva[2], Nayara Bernardes da Cunha[2], Daurea Abadia De-Souza[3], Rosana Maria dos Reis[4], Ana Carolina Japur de Sá Rosa-e-Silva[4]

[1]Department of Gynecology and Obstetrics, Faculty of Medicine, Federal University of Uberlândia, Uberlândia, MG, Brazil

[2]Multidisciplinary Residency Program in Clinical Nutrition, Multidisciplinary Residency in Health, Faculty of Medicine, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

[3]Department of Internal Medicine, Faculty of Medicine, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

[4]Department of Gynecology and Obstetrics, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, SP, Brazil

[*]**Corresponding author:** Camila Toffoli Ribeiro, Department of Gynecology and Obstetrics, Faculty of Medicine, Federal University of Uberlândia, Uberlândia, MG, Brazil

Citation: Toffoli-Ribeiro C, Silva CM, da Cunha NB, De-Souza DA, dos Reis RM, et al. (2020) Correlations between Measurements of Body Adiposity and Metabolic Variables in Patients with Polycystic Ovarian Syndrome: A Case-Control Study. Food Nutr J 5: 221. DOI: 10.29011/2575-7091.100121

Received Date: 15 July, 2020; **Accepted Date:** 20 July, 2020; **Published Date:** 27 July, 2020

Abstract

Objective: To study correlations between Insulin Resistance (IR) and Glucose Intolerance (GI) with body adiposity in women with Polycystic Ovary Syndrome (PCOS women) and controls.

Design, patients and Methods: A case-control study, including PCOS women (n=39) matched by Body Mass Index (BMI) and age to controls (n=35). We conducted Oral Glucose Tolerance Test (OGTT, 75g glucose), Homeostasis Model Assessment-estimated Insulin Resistance index (HOMA-IR), Electrical Bioimpedance (EB), Whole Body Densitometry (DXA), anthropometric measurements, and Visceral Adiposity Index (VAI).

Results: In PCOS women, HOMA-IR showed strong positive association with Fat Mass (FM, r=0.7164), Android Fat (AF, r=0.7729), and Fat/Lean Mass Ratio (FM/LM, r=0.7198) obtained by DXA and anthropometric measurements: Waist Circumference (WC, r=0.7857), Hip Circumference (HC, r=0.7104), BMI (r=0.7423) and Waist-To-Height Ratio (WHtR, r=0.7979). Moderate association was identified between OGTT and FM (r=0.5261), android fat (AF, r=0.5296), FM/LM (r=0.5296), WHtR (r=0.5065) and BMI (r=0.5156). In PCOS women, HOMA-IR showed moderate positive association with FM (r=0.6220) and FM/LM (r=0.6262) and negative with LM (r=-0.6220) obtained by EB. VAI presented strong (r=0.7004) and moderate (r= 0.6356) positive correlation with HOMA-IR and OGTT, respectively, in PCOS women. Subsequently, groups were subdivided into normal weight (BMI ≤ 24.9 Kg/m^2) and overweight (BMI ≥ 25.0 Kg/m^2). Among normal weight PCOS women, there was moderate correlation between OGTT and AF by DXA (r = 0.5308).

Conclusions: Adiposity in PCOS women could be sufficiently evaluated by BMI, WHtR, and VAI. DXA is appropriate for evaluating normal weight PCOS women due to the increased metabolic risk associated with android fat.

Keywords: Polycystic ovary syndrome, Glucose metabolism disorders, Whole body densitometry, Electrical bioimpedance, Anthropometric measurements

Introduction

Polycystic Ovary Syndrome (PCOS) is the most common endocrinopathy in women, with an estimated prevalence between 8 and 18% [1]. Women with PCOS show higher frequency of overweight and obesity (including central obesity), and increased risk of metabolic syndrome and glucose metabolism disorders [2]. The presence of Insulin Resistance (IR) is directly related to Body Mass Index (BMI) and central obesity, that is to say, adiposity has impact on metabolic risk [3]. Patients with IR show increase in the risk of Glucose Intolerance (GI) (Relative Risk [RR] of 2.48) and type 2 diabetes mellitus (RR of 4.43) [4]. Early identification of metabolic disease is advised and periodic clinical and laboratory evaluation has been indicated to women with PCOS from their second decade of life on [5]. Appropriate methods to evaluate adiposity in PCOS women

should present great accuracy, reproducibility, and possibility of large scale use in clinical practice, that is, easily accessible low-cost methods with fast application. Among the methods available for evaluating body composition, Whole Body Densitometry (DXA) and Electrical Bioimpedance (EB) are included. The DXA method evaluates the distribution of body fat and shows high accuracy. However, it is not portable, has elevated cost, and requires specialized operators [6]. The EB equipment is easily handled and affordable, some models are portable, in other words, they can be used at the bedside. Nevertheless, single-frequency EB equipment shows limitations in patients with alterations in body water distribution [6].

Among the most frequently used anthropometric methods for the clinical evaluation of adiposity, Body Mass Index (BMI), Waist (WC) and Hip (HC) circumference measurements, and the Waist-to-Hip Ratio (WHR) are included. However, anthropometric methods present variable reproducibility and limitations regarding the capacity of evaluating cardiometabolic risk. More specifically, individuals classified as normal weight by BMI may show increase of metabolic risk depending on body composition, that is, on the amount of Fat Mass (FM) and Lean Mass (LM) [7,8]. Moreover, it is necessary to clarify whether the indices including anthropometric variables in their formula can reproduce the results of gold standard methods of body composition evaluation. Recently, the Waist-to-Height Ratio (WHtR) and Visceral Adiposity Index (VAI) have been indicated as methods capable of evaluating abdominal fat [9,10]. Considering that in PCOS women visceral fat may elevate the risk of IR, if the association between anthropometric indices and the amount of abdominal fat is demonstrated, the indices could be used to replace DXA or EB, as a low cost alternative to evaluate metabolic risk in PCOS women.

The aim of this study was to analyze, in women with PCOS and controls, the correlations between IR and GI with body adiposity assessed by anthropometrics, EB, DXA, and VAI. The secondary goal was to analyze whether PCOS women show higher metabolic risk (IR, GI and VAI, anthropometric measurements, and body composition) than control women paired according to BMI and age.

Method

Observational case-control study, developed in an outpatient gynecological endocrinology unit of a tertiary university hospital in Brazil, from 2015 to 2017. The study was approved by the Ethics Committee on Research with Human Beings. All the enrolled women agreed to participate in the study and signed an informed consent. Seventy-four women were analyzed, 39 PCOS women and 35 controls, at age between 18 and 35 years old, paired according to age and BMI (maximum difference of ± 2.0 kg/m^2. Each control was within the same BMI category as the PCOS case [11]). PCOS diagnosis was performed following the Rotterdam consensus criteria [12]. Women enrolled in the control group were found at the HCU-UFU outpatient family planning or general gynecology units. Control group was composed of women with spontaneous regular menstrual cycles with no history of infertility. Women using hormone medication, three months before recruitment, oral hypoglycemic drugs or weight loss inducing drugs, and pregnant or breastfeeding women were excluded from the study.

Glucose metabolism was assessed by the Homeostasis Model Assessment-estimated Insulin Resistance (HOMA-IR), calculated by the formula: HOMA-IR = glycemia (mg%) x insulin (μUI/ml)/405 [13]. Women who presented HOMA-IR > 2.7 were classified as IR carriers [14]. The dosage of basal insulin was performed using the chemoluminescence method (Roche Diagnóstica©, Brazil). The oral glucose tolerance test, carried out with 75 grams of glucose, was used as GI marker. The dosages of blood glucose were performed using the hexokinase method (Roche Diagnóstica©, Brazil). The interpretation of oral glucose tolerance test results was conducted in accordance with the parameters established by the American Diabetes Association [15]. Fasting lipid profile was evaluated by the dosage of total, High Density Lipoprotein (HDL) and Low Density Lipoprotein (LDL) cholesterol, and by the dosage of triglycerides (enzymatic colorimetric method, Roche Diagnóstica©, Brazil). Among anthropometric variables, we gauged body weight, height, and WC measurements (performed in the midpoint between the last costal margin and the iliac crest) and HC (performed in the largest diameter of the gluteal region). For WC and HC measurements, we used an inextensible anthropometric fiberglass tape with 0.1 cm of accuracy. For the analyses of WC and HC values, we adopted the mean value of three measurements. Subsequently, WHR, HWtR and BMI values were calculated [BMI = weight (kg)/ height (m)^2]. BMI values were classified according to the World Health Organization [11].

The evaluation by Electrical Bioimpedance (EB) was carried out using the equipment Biodynamics 310e, TBW©, following the standardized protocol. The evaluation by the DXA method was performed with the equipment Lunar Prodigy DXA System (software version 11.20), in accordance with standardized parameters [16]. We performed measurements referring to the amount of Fat Mass (FM) and Lean Mass (LM), in grams and percentage, and FM/LM index. In addition, measurements of fat distribution in different compartments were carried out, specifically android fat (lower limit in the horizontal line that links anterior superior iliac spines, upper limit defined as 20% above the bottom edge, in parallel with the chin line and laterally by waist margins). Appendicular Fat Index (AFI) was calculated using the formula: AFI = legs FM (g) + arms FM (g) / trunk FM (g), according to equipment specifications. VAI was calculated applying the mathematical formula: VAI = [Waist/(36.58 + (1.89 x BMI))] X (Triglycerides /0.81) X (1.52/HDL cholesterol), concentrations of triglycerides and HDL cholesterol in mmol/l [17]. The results obtained for PCOS women were compared with the results obtained for control women. Next, the following subgroups were constituted according to BMI categories: PCOS normal weight (PCOS-Nw, n = 20) and control normal weight (C-Nw, n = 16), with BMI up to 24.9 kg/m^2; PCOS overweight (SOP-Ow, n = 19) and control overweight

(C- Ow, n = 19), in which BMI was ≥ 25.0 kg/m2.

Statistical Analysis

Statistical analyses were performed using the program GraphPad Prism® version 6.00 for Windows; GraphPad Software, La Jolla California USA (www.graphpad.com) and the program BioEstat 5.0 (http://www.mamiraua.org.br/pt-br/downloads/programas/). Variables were studied using D'Agostino and Pearson method in terms of distribution pattern; they were then categorized into parametric and non-parametric variables. Continuous parametric variables were compared using paired t Student test and non-parametric variables were compared using paired Wilcoxon test. For the comparison between more than 2 groups of variables, ANOVA test was employed, with Tukey post-test for normal distribution variables, and Kruskall-Wallis with Dunn post-test for non-parametric variables. For correlation analyses, Pearson correlation coefficient was used when the analysis was performed between two parametric variables, and Spearman correlation coefficient, when the analysis was performed between two non-parametric variables. The correlation coefficient (r) was considered weak when the identified value was between 0.3 and 0.5; moderate when between 0.5 and 0.7; strong when between 0.7 and 0.9; and very strong when higher or equal to 0.9. Comparison among frequencies of discrete variables was carried out using Fisher test. Analyses were considered significant when $p < 0.05$ was identified, using two-tailed tests.

Results

PCOS and control groups showed similar mean age (25 versus 26 years, p = 0.5024). The medians of the analyzed anthropometric variables, including BMI, were similar between groups. No difference was identified for body composition evaluation by EB and DXA methods, except for the AFI, which was significantly lower in PCOS women (p = 0.0435) (Table 1). For fasting blood glucose, HOMA-IR index, serum lipids, as well as IR and GI frequency, similar mean values were demonstrated for both groups. PCOS women showed higher mean value for blood glucose after 2-hour overload (OGTT) (p = 0.0090) (Table 1).

	PCOS	Control	*p*
	(n=39)	(n=35)	
Anthropometric variables			
BMI (kg/m²)	24.43 (20.90 - 33.84)	24.20 (21.75 - 31.00)	0.728
Waist (cm)	83.50 (72.00 - 103.30)	81.00 (72.00 - 93.50)	0.466
Hip (cm)	102.00 (95.63 - 117.00)	101.00 (95.00 - 110.00)	0.9966
WHR	0.8109 (0.7553 - 0.8715)	0.8000 (0.7577 - 0.844)	0.2067
WHtR	0.5138 (0.4441 - 0.6284)	0.5000 (0.4565 - 0.5994)	0.2776
Bioimpedance			
FM (%)	30.80 (26.00 - 39.30)	31.40 (25.60 - 36.40)	0.6829
LM (%)	69.20 (60.70 - 74.00)	68.60 (63.60 - 74.40)	0.6829
FM/LM	0.4450 (0.3500 - 0.6425)	0.4600 (0.3400 - 0.5700)	0.5909
Densitometry			
FM (%)	39.20 (33.30 - 48.70)	43.40 (33.30 - 49.00)	0.4413
FM/LM	0.6400 (0.5000 - 0.9500)	0.7100 (0.5000 - 0.9100)	0.7273
Android Fat (%)	46.70 (34.40 - 54.90)	46.20 (35.90 - 53.90)	0.7425
Appendicular Fat Index	0.9200 (0.7400 - 1.1100)	1.040 (0.9500 - 1.1200)	**0.0435***

Metabolic variables			
HOMA-IR	1.910 (1.330 - 4.120)	1.975 (1.153 - 2.695)	0.0576
Fasting blood glucose (mg/dl)	87.00 (80.75 - 94.00)	86.00 (79.75 - 90.00)	0.2213
OGTT (mg/dl)	105.00 (90.50 - 118.00)	92.50 (83.50 - 103.30)	**0.0090***
Total cholesterol (mg/dl)	170.50 (150.3 - 200.30)	168.00 (148.5 - 194.5)	0.9473
HDL cholesterol (mg/dl)	47.50 (39.00 - 59.50)	49.50 (41.75 - 59.25)	0.5387
LDL cholesterol (mg/dl)	103.00 (86.30 - 121.50)	98.00 (87.70 - 126.5)	> 0.9999
Triglycerides (mg/dl)	85.85 (53.75 - 143.80)	78.00 (59.00 - 102.00)	0.3426
IR (n. %)	15 women	8 women	0.1386
	(38.46% of sample)	(22.22% of sample)	
GI (n. %)	3 women	0 women	1
	(7.69% of sample)	(0 % of sample)	

DXA: Whole Body Densitometry; EB: Electrical Bioimpedance; WHR: Waist-To-Hip Ratio; WHtR: Waist-to-Height Ratio; FM: Fat Mass; LM: Lean Mass; FM/LM: Fat Mass/Lean Mass; Appendicular Fat Index: arms FM + legs FM/trunk FM; HOMA-IR: glycemia (mg%) x insulin (µUI/ml)/405; OGTT: oral glucose tolerance test; Insulin Resistance (IR): HOMA-IR > 2.7; Glucose Intolerance (GI): fasting blood glucose ≥ 100mg% and/or after overload blood glucose ≥ 140 mg%. *$p < 0.05$. All the results were expressed in median (p25 - p75), except for IR and GI that are expressed in frequency (number and %)

Table 1: Comparative analyses between women included in PCOS and Control groups in relation to anthropometric variables, body composition by DXA and EB and metabolic variables.

In FM evaluation, FM/LM ratio, and android fat, by EB and DXA methods, higher values were identified in the overweight subgroups, with or without PCOS. The AFI was lower in women included in the PCOS-Ow group, in relation to all groups: PCOS-Nw ($p = 0.0002$), C-Nw ($p < 0.0001$) and C-Ow ($p = 0.0134$). No differences were identified for the values of AFI among the control women included in C-Nw or C-Ow groups, neither in the values of other measurements performed to evaluate body composition, by EB and DXA methods, in all groups (Table 2).

	PCOS		**Control**							
	PCOS-Nw (n = 20)	**PCOS-Ow (n = 19)**	**C-Nw (n = 19)**	**C- Ow (n = 16)**	**PCOS-Nw X C-Nw**	**PCOS-Ow X C-Ow**	**C-Nw X C-Ow**	**PCOS-Ow X C-Nw**	**PCOS-Nw X PCOS-Ow**	**PCOS-Nw X C-Ow**
Anthropometrics										
WHR	0.7688 (0.7444 - 0.8080)	0.8748 (0.8355 - 0.9332)	0.7912 (0.7374 - 0.8046)	0.8387 (0.7817 - 0.8748)	1	0.23	0	< 0.0001	< 0.0001	0

BMI (kg/m²)	21.16 (19.52 - 23.15)	33.84 (30.20 - 37.63)	22.14 (20.55 - 23.03)	31.03 (27.55 - 37.88)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	< 0.0001	< 0.0001
WHtR	0.4509 (0.4273 -0.4906)	0.622 (0.5849 - .6810)	0.4575 (0.4348 - 0.4865)	0.6066 (0.5378 - 0.6552)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Bioimpedance										
FM (%)	27.05 (25.48- 30.10)	39 (33.63 - 41.55)	25.8 (23.60 - 29.70)	37.5 (34.00 - 41.18)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	0	0
LM (%)	72.95 (69.90 - 74.53)	61 (58.45 - 66.38)	74.2 (70.30 - 76.40)	62.5 (58.83 - 66.00)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	0	0
FM/LM	0.37 (0.34 - 0.43)	0.635 (0.50 - 0.71)	0.35 (0.31 - 0.42)	0.6 (0.51 - 0.70)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	0	0
Densitometry										
FM	33.8 (28.38 - 37.33)	48.7 (45.70 - 52.70)	34.8 (29.70 - 41.10)	48.4 (45.78 - 54.53)	> 0.9999	> 0.9999	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Android Fat	34.75 (29.20 - 41.43)	54.9 (52.60 - 59.60)	36 (30.90 - 43.90)	53.9 (51.80 - 57.05)	0.9	0.94	< 0.0001	< 0.0001	< 0.0001	< 0.0001
FM/LM	0.51 (0.3925 - 0.5925)	0.95 (0.8400 - 0.1100)	0.53 (0.4200 - 0.6700)	0.935 (0.8425 -1.198)	0.8	0.85	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Appendicular Fat Index	1.015 (0.9000 - 1.205)	0.81 (0.6500 - 0.9300)	1.07 (1.010 - 1.150)	1 (0.8550 - 1.100)	1	0.0134*	0.6	< 0.0001	0	1

DXA: Whole Body Densitometry; EB: Electrical Bioimpedance; C-Nw: Controls Normal Weight; C- Ow: Controls Overweight; PCOS-Nw: PCOS Normal weight; PCOS- Ow: PCOS Overweight; WHR: Waist-to-Hip Ratio; BMI: Body Mass Index (weight/height2); WHtR: Waist-to-Height Ratio; FM: Fat Mass; LM: Lean Mass; FM/LM: Fat Mass/Lean Mass; Appendicular Fat Index: arms FM + legs FM/trunk FM; *p < 0.05. Results were expressed in median (p25 - p75).

Table 2: Comparative analyses performed between women included in PCOS and Control groups, subdivided in normal weight and overweight in relation to anthropometric variables, body composition by DXA and EB.

Among women with PCOS, strong correlation between HOMA-IR and anthropometric measurements WC, HC, BMI, WHR was demonstrated. There was a strong correlation between HOMA-IR and body composition evaluation by DXA, in relation to FM/LM index and measurements of FM and android fat. Moderate correlation between HOMA-IR and FM/LM index and measurements of FM and LM was identified in body composition evaluation by EB (Table 3).

	PCOS (n = 39)				CONTROL (n = 35)			
	HOMA-IR		OGTT		HOMA-IR		OGTT	
Anthropometrics	**p**	**r**	***p***	**r**	***p***	**r**	***p***	**r**
Waist (cm)	< 0.0001*	0.7857[c]	0.0030*	0.4750[a]	< 0.0001*	0.6805[b]	0.1	0.3
Hip (cm)	< 0.0001*	0.7104[c]	0.0133*	0.4034[a]	< 0.0001*	0.6297[b]	0.1	0.3
WHR	< 0.0001*	0.6399[b]	0.0223*	0.3749[a]	0.0086*	0.4434[a]	0.6	0.1
BMI (kg/m²)	< 0.0001*	0.7423[c]	0.0009*	0.5156[b]	< 0.0001*	0.6707[b]	0.2	0.2
WHtR	< 0.0001*	0.7979[c]	0.0014*	0.5065[b]	< 0.0001*	0.6652[b]	0.1	0.3
Bioimpedance								
FM (%)	< 0.0001*	0.6220[b]	0.1	0	< 0.0001*	0.6893[b]	0.0165*	0.4084[a]
LM (%)	< 0.0001*	-0.6220[b]	0.1	-0	< 0.0001*	-0.6893[b]	0.0165*	-0.4084[a]
FM/LM	< 0.0001*	0.6262[b]	0.0485*	0.3266[a]	< 0.0001*	0.6869[b]	0.0162*	0.4093[a]
Densitometry								
FM (%)	< 0.0001*	0.7164[c]	0.0007*	0.5261[b]	< 0.0001*	0.6989[b]	0.1	0.3
Android Fat (%)	< 0.0001*	0.7729[c]	0.0002*	0.5723[b]	< 0.0001*	0.7112[c]	0.1	0.3
Appendicular Fat Index	0.0061*	-0.4423[a]	0.0002*	-0.5619[b]	0.3	-0	0.9	-0
FM/LM	< 0.0001*	0.7198[c]	0.0006*	0.5296[b]	0.0001*	0.7417[c]	0.0317*	0.3691[a]

DXA: Whole Body Densitometry; EB: Electrical Bioimpedance; HOMA-IR: glycemia (mg%) x insulin (μUI/ml)/405; OGTT: Oral Glucose Tolerance Test; WHR: Waist-To-Hip Ratio; BMI: Body Mass Index (weight/height²); WHtR: Waist-to-Height Ratio; FM: Fat Mass; LM: Lean Mass; FM/LM: Fat Mass/Lean Mass; Appendicular Fat Index: arms + legs/trunk *p < 0.05; [a]weak correlation (0.3 ≤ r < 0.5); [b]moderate correlation (0.5 ≤ r < 0.7); [c]strong correlation (0.7 ≤ r < 0.9).

Table 3: Correlation analyses in PCOS and Control groups between HOMA-IR and OGTT with anthropometric variables and body composition by DXA and EB.

Among PCOS women, moderate correlation was demonstrated between OGTT and the anthropometric variables BMI and WHtR, and the variables FM, FM/LM, android fat and appendicular fat index obtained through DXA (Table 3). Specifically, for women classified as PCOS-Ow, there was moderate correlation between HOMA-IR and WHtR (r = 0.6593), while for PCOS-Nw, moderate correlation between OGTT and android fat was observed through DXA (r = 0.5308) (Figure 1).

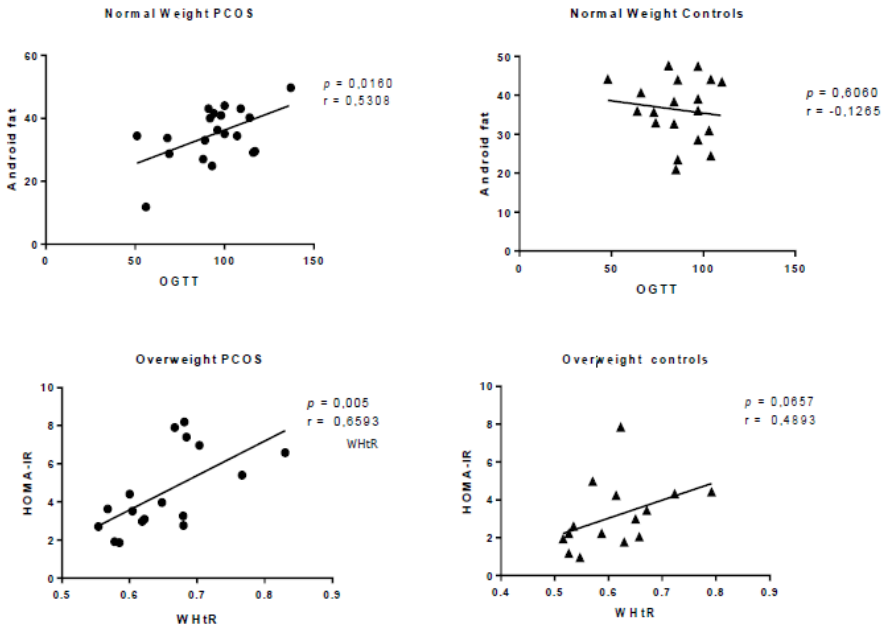

Figure 1: Correlation analyses between HOMA-IR and Waist-to-Height Ratio (WHtR) variables in overweight subgroups and between Oral Glucose Tolerance Test (OGTT) with android fat in normal weight subgroups between women included in PCOS and Control groups.

Weak correlation between OGTT and FM/LM index and FM and LM measurements was identified in body composition evaluation by EB (Table 3). We demonstrated that VAI showed strong correlation with HOMA-IR and moderate correlation with OGTT (Figure 2) among women with PCOS.

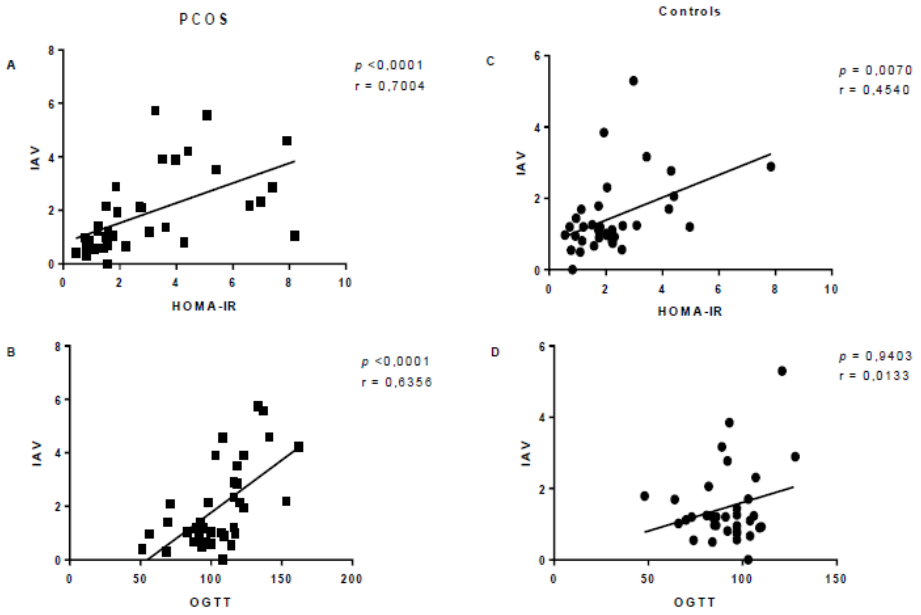

Figure 2: Correlation analyses between HOMA-IR and Oral Glucose Tolerance Test (OGTT) with Visceral Adiposity Index (VAI) between women included in PCOS and Control groups.

Discussion

In the present study, it was demonstrated that for women with PCOS HOMA-IR showed strong correlation with some parameters of body composition evaluation by DXA (FM/LM index and FM and android mass measurements), with most anthropometric measurements (WC, HC, BMI, WHtR) and with VAI. In accordance with the results demonstrated in our study, Carmina, et al. [18] also identified in PCOS women strong correlation between lower insulin sensitivity and central abdominal fat measurements by DXA. Despite the high cost of the method, DXA has been recommended in clinical studies on body composition evaluation due to its elevated accuracy [17,18]. In contrast, the use of anthropometric methods for evaluating IR risk in PCOS women is a subject of criticism in relation to the accuracy of different anthropometric variables [19-21]. The American Association of Clinical Endocrinologists proposes the use of WHR to evaluate IR risk in PCOS women [22]. However, in this study, we demonstrated that WHR was not the most sensitive marker for the evaluation of metabolic risk, similar to previously reported results by Lord, et al. [20]. More recently, as demonstrated in our study, WHtR has been pointed out as a better marker of metabolic risk in women with PCOS and in controls [9,23].

In body composition evaluation thorough single-frequency EB, it was demonstrated that HOMA-IR shows moderate correlation with FM/LM index and with FM and LM measurements, that is, less evident correlations than those demonstrated for DXA and for anthropometric methods. In disagreement with the results presented in this study, Ezeh, et al. [24] proposed that EB could be used advantageously in substitution of DXA, without sensitivity loss in body composition evaluation and with lower financial impact. In our study, we demonstrated that VAI showed strong correlation with HOMA-IR and moderate correlation with OGTT in women with PCOS. These results are concordant with the results obtained by Oh, Sung and Lee [10] who reported strong correlation between VAI and findings using tomography, considered a gold standard method for evaluating visceral fat and predicting IR. VAI has also been described as indicator of visceral fat effects, showing correlation with cardiometabolic risk in the general population [23].

The present study demonstrates that in women with PCOS 2-hour blood glucose after overload showed moderate correlation with all the parameters of body composition evaluation by DXA (FM and android fat measurements and FM/LM and appendicular fat indices), with anthropometric measurements (BMI and WHtR), and with VAI. In addition, it demonstrated that 2-hour blood glucose presented weak correlation with the parameters of body composition evaluation by EB (FM/LM Index). Although other investigators have also performed OGTT and investigated parameters of body composition evaluation by DXA in women with PCOS [25], no study specifically analyzing the correlations between anthropometric measurements and DXA parameters with 2-hour glucose in PCOS women has been found. Bi, et al. [26] investigated the correlations between body composition evaluation performed by DXA and anthropometric measurements with OGTT results in obese women not diagnosed with PCOS. The investigators concluded that DXA shows results superior to anthropometrics in the correlation with glucose metabolism disorders in obese women. In disagreement with the results obtained in our study, Ezeh, et al. [24] identified strong correlation between the parameters of body composition evaluation obtained using EB and intravenous glucose infusion test in PCOS women.

It was also demonstrated, in this study, that women included in the overweight PCOS group showed lower appendicular fat index than the women included in the other groups, more specifically, overweight controls, normal weight PCOS, and normal weight controls. To the best of our knowledge, it represents an unprecedented result in the literature, although greater trunk and lower limbs FM ratio has been demonstrated in PCOS [27]. Appendicular fat has been considered a protective factor against metabolic syndrome in the general population [28], once the predominance of fat mass in the appendices presumes lower amount of visceral fat, in other words, lower cardiovascular risk. The demonstration of lower AFI values in women with PCOS suggests that AFI is a marker of relevant cardiometabolic risk, peculiar to this condition. In the study, we demonstrated that PCOS women showed greater mean value for 2-hour blood glucose after overload (OGTT), what is in agreement with the results in the literature [25,29]. Furthermore, WC and WHR mean values were similar between PCOS women and controls, what goes against the results from other investigators [24,30]. In the attempt to clarifying these results, we may claim that the women enrolled in the sample of the present study were fairly young. PCOS phenotypic manifestations might take more time to appear, once they are influenced by years of chronic exposure to elevated levels of androgen [31]. The demonstration that WC and WHC were similar between PCOS and control women, concomitantly with the identification of lower AFI in POCS-Ow women, suggests that phenotypic manifestations are more subtle in young patients, and then DXA is more sensitive to this evaluation. The rigor in pairing the groups of the study, respecting the range of 2 kg/m^2 in BMI, as well as the observance of the same BMI category at recruitment, is another possible explanation. An example of how the control for confusing variables might interfere in the outcomes is the study by Pazderska, et al. [32]. These investigators identified that fasting insulin, triglycerides, and HOMA-IR were higher in PCOS women than in controls paired according to BMI. However, all the differences they found did not persist after performing the control to WC. In our study, the strict pairing resulted in WC mean values similar among groups. It might have an explanation for the similarity among the other metabolic parameters between PCOS and controls, including for IR.

IR prevalence was similar among PCOS and control women, while OGTT was higher in PCOS women. Probably, when there is IR, the presence of PCOS accelerates the evolution of metabolic disturbance, facilitating the progression towards GI in women with

the same BMI. HOMA-IR elevated with the increase of BMI both in PCOS and in control women, a fact that is in agreement with the results from other researchers [33]. It was evaluated whether EB and DXA could add relevant information to the care of normal weight women with PCOS. It is reported in the literature that in the normal weight PCOS group, when there is predominance of visceral fat, there is lower sensitivity to insulin [25,34]. Therefore, phenotypic heterogeneity in normal weight PCOS could have direct impact on the risk of glucose metabolism disorders, particularly bringing benefits to these patients thorough the methods of body composition evaluation [18]. In accordance with the hypothesis formulated, our study demonstrated moderate correlation between android fat and GI only in normal weight PCOS women, but not in control women at the same weight range. The major strengths of this study were the rigorous control in group pairing and the use of high accuracy methodology (DXA). In addition, the study has an eminently practical character, aiming to offer answers in terms of the benefit of adopting methods of body composition evaluation in clinical care routine of POCS patients. As main fragility, we must mention sampling size, what has limited the analysis of subgroups per BMI range.

Conclusion

Adiposity evaluation of PCOS women in the clinical setting can be carried out based on VAI calculation and anthropometric measurements, among them BMI and WHtR stands out given their correlation with metabolic risk. The best practical application of body composition methods lies on the evaluation of normal weight PCOS women, once in the presence of larger amount of android fat by DXA the cardiometabolic risk increases indeed. Single-frequency EB shows limited contribution in adiposity evaluation in PCOS women.

Statement of Authorship

Camila Toffoli Ribeiro, Catarina Mendes Silva and Nayara Bernardes da Cunha participated in the study design, statistical analyses, interpretation of data, and manuscript drafting. Daurea Abadia De-Souza, Rosana Maria dos Reis and Ana Carolina Japur de Sá Rosa e Silva participated in the study design, data interpretation and critical revision of the manuscript for important intellectual content. All authors approved the final version for submission.

Conflict of Interest Statement and Funding Sources

None of the authors had any personal or financial conflict of interest.

References

1. Sirmans SM, Pate KA (2013) Epidemiology, diagnosis, and management of polycystic ovary syndrome. Clin Epidemiol 6:1-13.
2. Lim SS, Davies MJ, Norman RJ, Moran LJ (2012) Overweight, obesity and central obesity in women with polycystic ovary syndrome: a systematic review and meta-analysis. Hum Reprod Update 18: 618-637.
3. Randeva HS, Tan BK, Weickert MO, Lois K, Nestler JE, et al. (2012) Cardiometabolic aspects of the polycystic ovary syndrome. Endocr Rev 33: 812-841.
4. Moran LJ, Misso ML, Wild RA, Norman RJ (2010) Impaired glucose tolerance, type 2 diabetes and metabolic syndrome in polycystic ovary syndrome: a systematic review and meta-analysis. Hum Reprod Update 16: 347-363.
5. Teede HJ, Misso ML, Costello MF, Dokras A, Laven J, et al. (2018) Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome. Human Reprod 33: 1602-1618.
6. Andreoli A, Scalzo G, Masala S, Tarantino U, Guglielmi G (2009) Body composition assessment by dual-energy X-ray absorptiometry (DXA). Radiol Med 114: 286-300.
7. Lang PO, Trivalle C, Vogel T, Proust J, Papazian JP (2015) Markers of metabolic and cardiovascular health in adults: Comparative analysis of DEXA-based body composition components and BMI categories. J Cardiol 65: 42-49.
8. Sharp DS, Andrew ME, Burchfiel CM, Violanti JM, Wactawski-Wende J (2012) Body mass index versus dual energy x-ray absorptiometry-derived indexes: predictors of cardiovascular and diabetic disease risk factors. Am J Hum Biol 24: 400-405.
9. Swainson MG, Batterham AM, Tsakirides C, Rutherford ZH, Hind K (2017) Prediction of whole-body fat percentage and visceral adipose tissue mass from five anthropometric variables. PLoS One 12: e0177175.
10. Oh J-Y, Sung YA, Lee HJ (2013) The visceral adiposity index as a predictor of insulin resistance in young women with polycystic ovary syndrome. Obesity (Silver Spring) 21: 1690-1694.
11. World Health Organization. Obesity: Preventing and Managing the Global Epidemic. Geneva: World Health Organization; 2000. Report of a WHO Consultation on Obesity.
12. Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group (2004) Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome. Fertil Steril 81: 19-25.
13. Jensterle M, Weber M, Pfeifer M, Prezelj J, Pfutzner A, et al. (2008) Assessment of insulin resistance in young women with polycystic ovary syndrome. Int J Gynaecol Obstet 102: 137-140.
14. Geloneze B, Vasques ACJ, Stabe CFC, Pareja JC; de Lima Rosado LEFP, et al. (2009) HOMA1-IR and HOMA2-IR indexes in identifying insulin resistance and metabolic syndrome. Arq Bras Endocrinol Metab 53: 281-287.
15. Association AD (2018) 2. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes-2018. Diabetes Care 41: S13-27.
16. Hangartner TN, Warner S, Braillon P, Jankowski L, Shepherd J (2013) The Official Positions of the International Society for Clinical Densitometry: acquisition of dual-energy X-ray absorptiometry body composition and considerations regarding analysis and repeatability of measures. J Clin Densitom 16: 520-536.

17. Amato MC, Giordano C, Galia M, Criscimanna A, Vitabileet S, al. (2010) Visceral Adiposity Index: a reliable indicator of visceral fat function associated with cardiometabolic risk. Diabetes Care 33: 920-922.

18. Carmina E, Bucchieri S, Esposito A, Puente AD, Mansueto P, et al. (2007) Abdominal Fat Quantity and Distribution in Women with Polycystic Ovary Syndrome and Extent of Its Relation to Insulin Resistance. J Clin Endocrinol Metab 92: 2500-2505.

19. Carmina E, Guastella E, Longo RA, Rini GB, Lobo RA (2009) Correlates of increased lean muscle mass in women with polycystic ovary syndrome. Eur J Endocrinol 161: 583-589.

20. Lord J, Thomas R, Fox B, Acharya U, Wilkin T (2006) The central issue? Visceral fat mass is a good marker of insulin resistance and metabolic disturbance in women with polycystic ovary syndrome. BJOG 113: 1203-1209.

21. Behboudi-Gandevani S, Ramezani Tehrani F, Cheraghi L, Azizi F (2016) Could "a body shape index" and "waist to height ratio" predict insulin resistance and metabolic syndrome in polycystic ovary syndrome? Eur J Obstet Gynecol Reprod Biol 205: 110-114.

22. Goodman NF, Cobin RH, Futterweit W, Glueck JS, Legro RS, et al. (2015) American association of clinical endocrinologists, american college of endocrinology, and androgen excess and pcos society disease state clinical review: guide to the best practices in the evaluation and treatment of polycystic ovary syndrome - part 2. Endocr Pract 21: 1415-1426.

23. Savva SC, Lamnisos D, Kafatos AG (2013) Predicting cardiometabolic risk: waist-to-height ratio or BMI. A meta-analysis. Diabetes, Metab Syndr Obes 6: 403-419.

24. Ezeh U, Pall M, Mathur R, Azziz R (2014) Association of fat to lean mass ratio with metabolic dysfunction in women with polycystic ovary syndrome. Hum Reprod 29: 1508-1517.

25. Satyaraddi A, Cherian KE, Kapoor N, Kunjummen AT, Kamath MS, et al. (2019) Body composition, metabolic characteristics, and insulin resistance in obese and nonobese women with polycystic ovary syndrome. J Hum Reprod Sci 12: 78-84.

26. Bi X, Seabolt L, Shibao C, M Buchowski, H Kang, et al. (2015) DXA-Measured Visceral Adipose Tissue Predicts Impaired Glucose Tolerance and Metabolic Syndrome in Obese Caucasian and African American Women. Eur J Clin Nutr 69: 329-336.

27. Yucel A, Noyan V, Sagsoz N (2006) The association of serum androgens and insulin resistance with fat distribution in polycystic ovary syndrome. Eur J Obstet Gynecol Reprod Biol 126: 81-86.

28. Park SY, Kwon KY, Kim JH, Choi HH, Han KH, et al. (2014) Association between Appendicular Fat Mass and Metabolic Risk Factors. Korean J Fam Med 35: 182-189.

29. Mario FM, Graff SK, Spritzer PM (2017) Adiposity Indexes as Phenotype-Specific Markers of Preclinical Metabolic Alterations and Cardiovascular Risk in Polycystic Ovary Syndrome: A Cross-Sectional Study. Exp Clin Endocrinol Diabetes 125: 307-315.

30. Al-Jefout M, Alnawaiseh N, Al-Qtaitat A (2017) Insulin resistance and obesity among infertile women with different polycystic ovary syndrome phenotypes. Sci Rep 7: 5339.

31. Pedroso DCC, Melo AS, Carolo AL, Vieira CS, Rosa e Silva ACJS, et al. (2012) Frequency and risk factors for metabolic syndrome in adolescents and adults women with polycystic ovary syndrome. Rev Bras Ginecol Obstet 34: 357-361.

32. Pazderska A, Tun TK, Phelan N, McGowan A, Sherlock M, et al. (2018) In women with PCOS, waist circumference is a better surrogate of glucose and lipid metabolism than disease status per se. Clin Endocrinol (Oxf.) 88: 565-574.

33. Martinez KE, Tucker LA, Bailey BW, LeCheminant JD (2017) Expanded Normal Weight Obesity and Insulin Resistance in US Adults of the National Health and Nutrition Examination Survey. J Diabetes Res 2017: 9502643.

34. Svendsen PF, Nilas L, Nørgaard K, Jensen J-EB, Madsbad S (2008) Obesity, body composition and metabolic disturbances in polycystic ovary syndrome. Hum Reprod 23: 2113-2121.