Original Research

Polycystic Ovary Syndrome Presents Higher Sympathetic Cardiac Autonomic Modulation that is not altered by Strength Training

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ABSTRACT

International Journal of Exercise Science 9(5): 554-566, 2016. Polycystic ovary syndrome (PCOS) may present important comorbidities, such as cardiovascular and metabolic diseases, which are often preceded by changes in cardiac autonomic modulation. Different types of physical exercises are frequently indicated for the prevention and treatment of PCOS. However, little is known about the effects of strength training on the metabolic, hormonal, and cardiac autonomic parameters. Therefore, our aim was to investigate the effects of strength training on the autonomic modulation of heart rate variability (HRV) and its relation to endocrine-metabolic parameters in women with PCOS. Fifty-three women were divided into two groups: CONTROL (n=26) and PCOS (n=27). The strength training lasted 4 months, which was divided into mesocycles of 4 weeks each. The training load started with 70% of one repetition maximum (1RM). Blood samples were collected before and after intervention for analysis of fasting insulin and glucose, HOMA-IR, testosterone, androstenedione and testosterone/androstenedione (T/A) ratio. Spectral analysis of HRV was performed to assess cardiac autonomic modulation indexes. The PCOS group presented higher insulin and testosterone levels, T/A ratio, along with increased sympathetic cardiac autonomic modulation before intervention. The training protocol used did not cause any change of endocrine-metabolic parameters in the CONTROL group. Interestingly, in the PCOS group, reduced testosterone levels and T/A ratio. Additionally, strength training did not have an effect on the spectral parameter values of HRV obtained in both groups. Strength training was not able to alter HRV autonomic modulation in women with PCOS, however may reduce testosterone levels and T/A ratio.

KEY WORDS: Heart rate variability, physical exercise

INTRODUCTION

Polycystic ovary syndrome (PCOS) is the most common endocrine disorder in women, with a prevalence of up to 15% (9, 16). Although the pathophysiological mechanisms have yet to be

totally clarified, the presence of multifactorial events related to genetic factors, body composition, and endocrine-metabolic disorders (especially high levels of androgen) have been observed (7, 9, 16, 19, 41). These alterations appear to promote insulin resistance and hyperinsulinemia by modifying the mechanisms involved in the regulation of the responses of the insulin receptors, and consequently, in glucose absorption (29, 30). In contrast, insulin resistance seems to amplify theca steroidogenesis, an intrinsic abnormality, by stimulating the increase of androgen synthesis (7, 41).

Additionally, the literature has shown that the excess of androgens present in women with PCOS is a contributing factor in the development of a number of disorders, including some cardiovascular diseases such as atherosclerosis and hypertension (4, 16). Moreover, increased insulin resistance can lead to the development of type 2 diabetes, general and abdominal obesity, and cardiac autonomic control damage, which may further worsen the prognosis (4, 9, 22, 34, 35, 36, 41). Therefore, studies on new therapeutic strategies should be conducted to reduce risks in women exposed to these conditions.

The use of a structured aerobic physical exercise program has resulted in a global improvement in cardiovascular and metabolic parameters including insulin sensitivity, hormonal profile and cardiac autonomic balance. (10, 20, 29, 44). In contrast, strength training is not commonly used in the treatment of PCOS. However, some studies with other populations have shown that strength training can provide health-related benefits such as the reduction of body fat and a decrease in the risks of hypertension and diabetes (33, 40, 44). In this case, strength training seems to improve the insulin action/sensitivity in the muscles of individuals with diabetes and overweight patients as well as in healthy persons (2,18). This type of training can also promote different adaptations in hormonal profiles, including those of the androgenic hormones (42, 43).

These findings are important because the reduction of insulin sensitivity and chronic hyperglycemia may have negative effects on cardiac autonomic control, especially in terms of heart rate variability (HRV), by increasing the influence of the sympathetic component and reducing the influence of the parasympathetic component in the heart. Therefore, this autonomic imbalance may serve as a pathway for the development and aggravation of cardiovascular diseases (3, 30, 37). Interestingly, it was suggested that the increase of sympathetic cardiac autonomic modulation could be related to high levels of testosterone (8), which further emphasizes the importance of evaluating the effects of strength training in women with PCOS.

Although the health benefits of strength training have been well recognized, scientific evidence is still scarce, especially in women with PCOS. Therefore, in the present study was investigated the effects of periodized strength training on cardiac autonomic parameters and its correlation with metabolic and endocrine parameters in women with PCOS.

METHODS

Participants
A convenience sample of 53 participants were recruited and divided into two groups: control group (CG; N= 26) and group with the polycystic ovary syndrome (PCOS group; N= 27). The participants were aged between 18 and 37 years, had a body mass index (BMI) between 18.0 and 39.9 kg/m², and were not involved in any regular (two or more times a week) or instructed physical exercises at the time of the study. For the CG, the range of the regular menstrual cycle interval was estimated to be 22–35 days, with a duration of 3–7 days (11). PCOS was diagnosed based on the criteria established by the Rotterdam consensus (16), and the presence of at least two of the following criteria: menstrual irregularity (cycle length >35 days or variation between consecutive cycles of >10 days); presence of hirsutism evaluated by a Ferriman-Gallwey score >8, severe acne and alopecia; hyperandrogenism (total testosterone concentration >80 ng/dL); or ultrasound evidence of polycystic ovaries. All volunteers with PCOS selected for the study had polycystic ovaries; 70.4% presented with biochemical hyperandrogenism, 66.7% had clinical hyperandrogenism, and 88.9% had irregular menstrual cycles. The following items were used as exclusion criteria: presence of systemic diseases and musculoskeletal disorders that prevented the women from practicing physical exercises; presence of congenital adrenal hyperplasia, androgen-secreting neoplasms, Cushing's syndrome, tabagism, and pregnancy; and use of hormonal contraceptives or drugs that interfere with the hypothalamic-pituitary axis or cardiac autonomic modulation.

This study was conducted in accordance with the ethical standards set forth in the Helsinki Declaration of 1975 and approved by the Human Research Ethics Committee of the Clinical Hospital of the School of Medicine of Ribeirão Preto, University of São Paulo, Brazil (case HCRP N. 13475/2009). The evaluations were performed before and after the physical training period and all volunteers provided their free and informed consent.

Protocol
The strength training program lasted for 4 months, which was divided into mesocycles of 4 weeks each. The calculation of one repetition maximum (1RM) was performed for each volunteer (32) and linear periodization was used to gradually decrease the volume and increase the intensity during the training. The exercises included: 1) bench press, 2) leg extension, 3) front lat pull down, 4) leg curl, 5) lateral raise, 6) leg press (45°), 5) triceps pulley, 6) calf leg press, 7) arm curl, and 8) abdominal. The training load started with 70% of 1RM, and each exercise was repeated for 12 repetitions. In the first 3 weeks of each mesocycle, the exercises were performed three times/week and the intensity was increased by 5% per week. In the fourth week, these exercises were performed twice/week and the intensity were reduced by 5% (1).

Blood samples were collected during the follicular phase, and at any time in those with amenorrhea. The tests were performed in the Gynecology Laboratory of the HC-FMRP,

between 07:00 and 09:00 am, after a 12-h fast. Blood (15mL) was collected into conical plastic tubes (BD-Becton Dickinson, Plymouth, UK). The blood samples for the analysis of fasting insulin were stored in vacuum tubes, with a separating gel barrier. The blood samples for the other tests, except those for the analysis of fasting glucose, were stored under vacuum in tubes containing EDTA fasting blood glucose levels was analyzed immediately after collection. Blood was then centrifuged at 2500 rpm in a CT 5000 centrifuge *(*Cientec Laboratory Equipments, São Paulo, Brazil) at room temperature (20–24°C) for 10 min and transferred to sealed plastic tubes (Eppendorf tubes). Serum was stored at -80°C for the simultaneous determination of all serum variables. The ELISA method was used for the analysis of sex hormone binding globulin (SHBG). Insulin, prolactin, and thyroid stimulating hormone levels were measured by using chemiluminescence. Glucose was measured by using the glucose oxidase method. 17-Hydroxyprogesterone, testosterone, and androstenedione were measured by means of radioimmunoassay. To detect insulin resistance (>2.71 nmol× µU/L), the following equation was used: HOMA-IR (homeostatic model assessment-insulin resistance) = [(fasting glucose in mg/dL× 0.05551*)* ×(fasting insulin in µU/mL/22.5)*]* (13, 24). The free androgen index (FAI) was calculated by using the equation [TT (nmol/L)/SHBG (nmol/L)]× 100.

Transvaginal pelvic ultrasound was performed by using Voluson 730 Pro and Expert (GE Medical Systems, Kretztechnik, Zipf, Austria). The ovarian volume and the number and size of follicles (when present) were determined. The calculation of ovarian volume was performed by using the formula for a prolate ellipsoid (15).

Body composition was determined via dual energy x-ray absorptiometry, by using the latest program of the system (QDR Discovery Series; Hologic Inc., Waltham, *MA*, USA). This test was conducted at the Science Center of Images and Medical Physics of the HC-FMRP, Brazil. In this scanning technique, an x-ray generator emits pulses of double-energy alternate radiation of 70 and 140 Kv (14). The photons pass through the tissues of the subject, and thus evaluate total body fat.

Spectral analysis of HRV was performed to assess cardiac autonomic modulation. The volunteers were requested to refrain from consuming alcoholic beverages and caffeine or from practicing physical exercises. They were requested to maintain a regular diet in the 48 h before the examination. The recording for spectral analysis of HRV was accomplished by using ECG signals (AD Instruments, Sydney, Australia), between 8:00 and 11:00am, according to the following protocol: 20 min in the supine position on a special motorized (automated) tilt table (orthostatic table); this recording period was followed by 10 min of recording with initial phase adaptation and 10 min of final recording in the supine position. Subsequently, the table engine was turned on and the volunteers passively shifted from the supine position to the orthostatic position (90°) for 10 min. The HRV analysis was performed by using custom-made computer software (CardioSeries version 2.4; http://sites.google.com/site/cardioseries).

The RR interval (RRi) values obtained were resampled (3 Hz) by using cubic spline interpolation to adjust the time interval between heartbeats, and were divided into segments

with 512 values each, with 50% overlapping (Welch protocol). Each RRi stationary segment was subjected to fast Fourier transform, after applying a Hanning window function. The oscillatory components were classified as either low frequency (LF: 0.04–0.15 Hz) high frequency (HF: 0.15–0.5 Hz). The mean values of the power spectral densities of RRi in both bands (LF and HF) were expressed in absolute units (ms²). The relative power (%), also known as normalized units (nu), in each frequency band, as well as the LF/HF ratio powers, were calculated by subtracting the very low frequency (VLF<0.04 Hz) values. The normalization tends to minimize the effect of changes in the total power on the values of the LF and HF components (17, 23).

Statistical Analysis
The Shapiro-Wilk test was applied to determine the normality of the sample, with 95% significance. The effects of PCOS and of the strength training were evaluated by using two-way ANOVA, and data are presented as means ± S.E.M. (standard error of the mean). The comparison between groups was analyzed statistically with the Student-Newman-Keuls test, whenever necessary. The statistical significance level was established at 5% ($p < 0.05$). The associations between the percentage changes in LF/HF ratio and the endocrine-metabolic variables were verified by using the Spearman's rank correlation coefficient with Spearman's rank correlation test. For the statistical analysis and charts, Sigma Stat software (version 11.0) was used (Systat Software Inc., San Jose, CA, USA).

RESULTS

The age and height of the women were similar in both groups: CG (31 ± 1.0 years and 1.62 ± 0.1 m) and PCOS (29 ± 1.1 years and 1.61 ± 0.1 m). Table 1 shows the values of the hemodynamic and metabolic-endocrine parameters. No significant differences were observed in any of the hemodynamic parameters between the CG and PCOS groups, before and after strength training. The evaluation of endocrine-metabolic parameters showed that the PCOS group, when compared with the CG, presented significantly higher levels of testosterone (p = 0.041) and insulin (p = 0.037) before strength training. Moreover, strength training in the CG did not cause any significant change in the values of endocrine-metabolic parameters. Interestingly, strength training reduced testosterone levels (p = 0.021) and T/A ratio (p = 0.004) in both groups. On the other hand, androstenedione levels remain unchanged after 4 months of training (p = 0.306).

Table 2 shows the spectral parameter values of HRV obtained in the supine and orthostatic positions in both groups. In the supine position, there were no differences between the study groups, and strength training did not cause any changes. However, during the tilt test, in the orthostatic position, the PCOS group presented higher values of LF band oscillations in absolute (p = 0.035) and normalized (p = 0.049) units and lower values of HF band oscillations in normalized (p = 0.049) units compared with the CG. Consequently, we also observed a higher LF/HF ratio value in the PCOS group (p = 0.047). However, strength training did not have a significant effect on the spectral values obtained in both groups.

Table 1. Hemodynamic and endocrine-metabolic parameters among women in the CG and PCOS groups before and after strength training.

	CG (n = 26)		PCOS (n = 27)		PCOS		Strength training		Interaction	
	Before	**After**	**Before**	**After**	$F_{(DF)}$	*p*	$F_{(DF)}$	*p*	$F_{(DF)}$	*p*
Hemodynamic values										
Heart rate, bpm	69 ± 1.7	68 ± 1.5	66 ±1.3	67 ± 1.7	$F_{(1,102)}$0.58	*0.45*	$F_{(1,102)}$0.01	*0.98*	$F_{(1,102)}$0.14	*0.71*
Systolic blood pressure, mmHg	111 ± 3	109 ± 2	115 ± 3	117 ± 4	$F_{(1,102)}$.62	*0.13*	$F_{(1,102)}$1.09	*1.11*	$F_{(1,102)}$0.72	*0.77*
Diastolic blood pressure, mmHg	75 ± 3	70 ± 3	77 ± 4	76 ± 4	$F_{(1,102)}$.45	*0.24*	$F_{(1,102)}$0.83	*0.73*	$F_{(1,102)}$1.19	*0.63*
Mean blood pressure, mmHg	90 ± 3	86 ± 2	93 ± 4	94 ± 4	$F_{(1,102)}$.27	*0.39*	$F_{(1,102)}$0.45	*0.52*	$F_{(1,102)}$0.64	*0.44*
Endocrine-metabolic values										
Weight, kg	70.9 ± 3.1	70.7 ± 2.9	74.4 ± 3.1	73.9 ± 3.1	$F_{(1,102)}$1.36	*0.246*	$F_{(1,102)}$0.01	*0.996*	$F_{(1,102)}$0.01	*0.949*
BMI, kg/m²	26.9 ±1.1	26.9 ± 1.1	28.7 ± 1.2	28.5 ± 1.1	$F_{(1,102)}$2.48	*0.118*	$F_{(1,102)}$0.01	*0.991*	$F_{(1,102)}$0.01	*0.954*
Body fat, %	38.6 ± 1.0	39.3 ± 1.1	39.8 ± 0.8	38.6 ± 0.6	$F_{(1,102)}$0.12	*0.724*	$F_{(1,102)}$0.12	*0.730*	$F_{(1,102)}$1.11	*0.294*
Testosterone, ng/dL	72.6 ± 5.1	64.9 ± 2.9	87.7 ± 6.8*	71.2 ± 5.0#	$F_{(1,102)}$4.29	*0.041*	$F_{(1,102)}$5.51	*0.021*	$F_{(1,102)}$0.71	*0.400*
Androstenedione, ng/dL	108.7± 6.9	108.4 ± 4.9	123.8 ± 9.0	139.3 ± 10.4+	$F_{(1,102)}$7.82	*0.006*	$F_{(1,102)}$0.85	*0.360*	$F_{(1,102)}$0.93	*0.338*
T/A ratio	0.74± 0.07	0.62 ± 0.04	0.75 ± 0.05	0.55 ± 0.04#	$F_{(1,102)}$0.30	*0.582*	$F_{(1,102)}$8.77	*0.004*	$F_{(1,102)}$0.93	*0.338*
SHBG	55.0 ± 5.7	46.9 ± 5.0	53.1 ± 3.9	44.96 ± 3.7	$F_{(1,102)}$0.17	*0.681*	$F_{(1,102)}$3.01	*0.086*	$F_{(1,102)}$0.01	*0.999*
FAI	169.5± 23.2	180.0 ± 22.6	197.1 ± 20.9	189.3 ± 20.7	$F_{(1,102)}$0.67	*0.413*	$F_{(1,102)}$0.01	*0.933*	$F_{(1,102)}$0.20	*0.659*
Fasting glucose, mg/dL	91.6 ± 2.8	89.2 ± 2.2	92.5 ± 3.0	86.0 ± 2.5	$F_{(1,102)}$0.19	*0.662*	$F_{(1,102)}$2.82	*0.096*	$F_{(1,102)}$0.59	*0.446*
Fasting insulin, μU/mL	6.22± 1.08	6.68 ± 0.98	9.60 ± 1.29*	8.85 ± 1.72	$F_{(1,102)}$4.46	*0.037*	$F_{(1,102)}$0.01	*0.913*	$F_{(1,102)}$0.21	*0.647*
HOMA-IR, nmol× μU/L	1.46± 0.30	1.54 ± 0.25	2.20 ± 0.30	1.99 ± 0.44	$F_{(1,102)}$3.16	*0.078*	$F_{(1,102)}$0.04	*0.841*	$F_{(1,102)}$0.17	*0.676*

All values are expressed as means ± S.E.M.CG, control group; PCOS, polycystic ovary syndrome; BMI, body mass index; SHBG, sex hormone binding globulin; FAI, free androgen index; bpm, beats per minute; mmHg, millimeters of mercury; kg, kilograms; kg/m², kilograms per square meter; %, percentage; ng/dL, nanograms per deciliter; nmol/L, nanomolar per liter; mg/dLmilligrams per deciliter; μU/mL, microunits per milliliter. *p< 0.05 compared with CG before training. #p<0.05 compared with PCOS before training. +p<0.005 compared with CG before training.

Table 2. Parameters of spectral analysis of the time series of RR intervals obtained in the supine position and during the tilt test in women from both groups (CG and PCOS) before and after strength training.

	CG (n = 26)		PCOS (n = 27)		PCOS		Strength training		Interaction	
	Before	**After**	**Before**	**After**	$F_{(DF)}$	*p*	$F_{(DF)}$	*p*	$F_{(DF)}$	*p*
Spectral analysis—supine										
RRi,ms	888 ± 23	886 ± 24	906 ± 18	903 ± 22	$F_{(1,102)}$0.67	*0.414*	$F_{(1,102)}$0.01	*0.917*	$F_{(1,102)}$0.01	*0.987*
Variance, ms²	2663 ± 597	2914 ± 692	2881 ± 492	2314 ± 304	$F_{(1,102)}$0.13	*0.723*	$F_{(1,102)}$0.09	*0.768*	$F_{(1,102)}$0.58	*0.477*
LF, ms²	829 ± 223	704 ±137	871 ± 242	591 ± 81	$F_{(1,102)}$0.04	*0.846*	$F_{(1,102)}$1.23	*0.271*	$F_{(1,102)}$0.18	*0.673*
HF, ms²	1165 ± 310	1473 ± 507	1138 ± 243	987 ±190	$F_{(1,102)}$0.60	*0.440*	$F_{(1,102)}$0.06	*0.813*	$F_{(1,102)}$0.48	*0.491*
LF, nu	43 ± 3	41± 4	43 ± 3	42± 3	$F_{(1,102)}$0.01	*0.924*	$F_{(1,102)}$0.23	*0.632*	$F_{(1,102)}$0.07	*0.797*
HF, nu	57 ± 3	59 ± 4	57± 3	58 ± 3	$F_{(1,102)}$0.01	*0.924*	$F_{(1,102)}$0.23	*0.632*	$F_{(1,102)}$0.07	*0.797*
LF/HF ratio	0.90 ± 0.11	0.89 ± 0.13	0.93 ± 0.15	0.90 ± 0.13	$F_{(1,102)}$0.02	*0.891*	$F_{(1,102)}$0.03	*0.868*	$F_{(1,102)}$0.01	*0.914*
Spectral analysis—tilt test										
RRi, ms	708 ±19	699 ±16	724 ±15	711 ±16	$F_{(1,102)}$0.72	*0.397*	$F_{(1,102)}$0.37	*0.542*	$F_{(1,102)}$0.01	*0.894*
Variance, ms²	1571 ± 242	1541 ± 212	1940 ± 256	1927 ± 241	$F_{(1,102)}$2.48	*0.118*	$F_{(1,102)}$0.01	*0.929*	$F_{(1,102)}$0.01	*0.973*
LF, ms²	584 ± 84	568 ± 77	830 ± 123*	821 ±159	$F_{(1,102)}$4.57	*0.035*	$F_{(1,102)}$0.01	*0.912*	$F_{(1,102)}$0.01	*0.974*
HF, ms²	329 ±131	246 ±71	258 ± 70	200 ± 41	$F_{(1,102)}$0.47	*0.493*	$F_{(1,102)}$0.70	*0.403*	$F_{(1,102)}$0.02	*0.881*
LF,nu	71 ± 3	74 ± 3	78 ± 2*	79 ± 2	$F_{(1,102)}$3.96	*0.049*	$F_{(1,102)}$0.62	*0.431*	$F_{(1,102)}$0.16	*0.694*
HF,nu	29 ±3	26 ± 3	22 ± 2*	21 ± 3	$F_{(1,102)}$3.96	*0.049*	$F_{(1,102)}$0.62	*0.431*	$F_{(1,102)}$0.16	*0.694*
LF/HF ratio	3.99 ± 0.62	4.32 ± 0.60	5.21 ± 0.77*	6.12 ± 0.96	$F_{(1,102)}$4.02	*0.047*	$F_{(1,102)}$0.69	*0.416*	$F_{(1,102)}$0.15	*0.701*

All values are expressed as means ± S.E.M. CG, control group; PCOS, polycystic ovary syndrome; RRi, RR interval; LF, low frequency; HF, high frequency; ms, millisecond; ms², millisecond squared; nu, normalized unit.*p<0.05 compared with CG before training.

Figures 1 and 2 present the results of the spectral analysis of HRV in the CG and PCOS groups, by comparing the values of the total variance (including LF and HF bands in absolute and normalized units) obtained in the supine and orthostatic positions (tilt test) before and after strength training. The results obtained during the tilt test in the CG (Figure 1) showed significant reductions in total variance, in the LF band in normalized units, and in the HF band

in absolute and normalized units, which significantly increased the LF/HF ratio. Strength training did not change the observed responses. The PCOS group (Figure 2) showed similar results to those seen in the CG, with the exception of the total variance, which did not differ in the transition from supine position to orthostatic position during the tilt test.
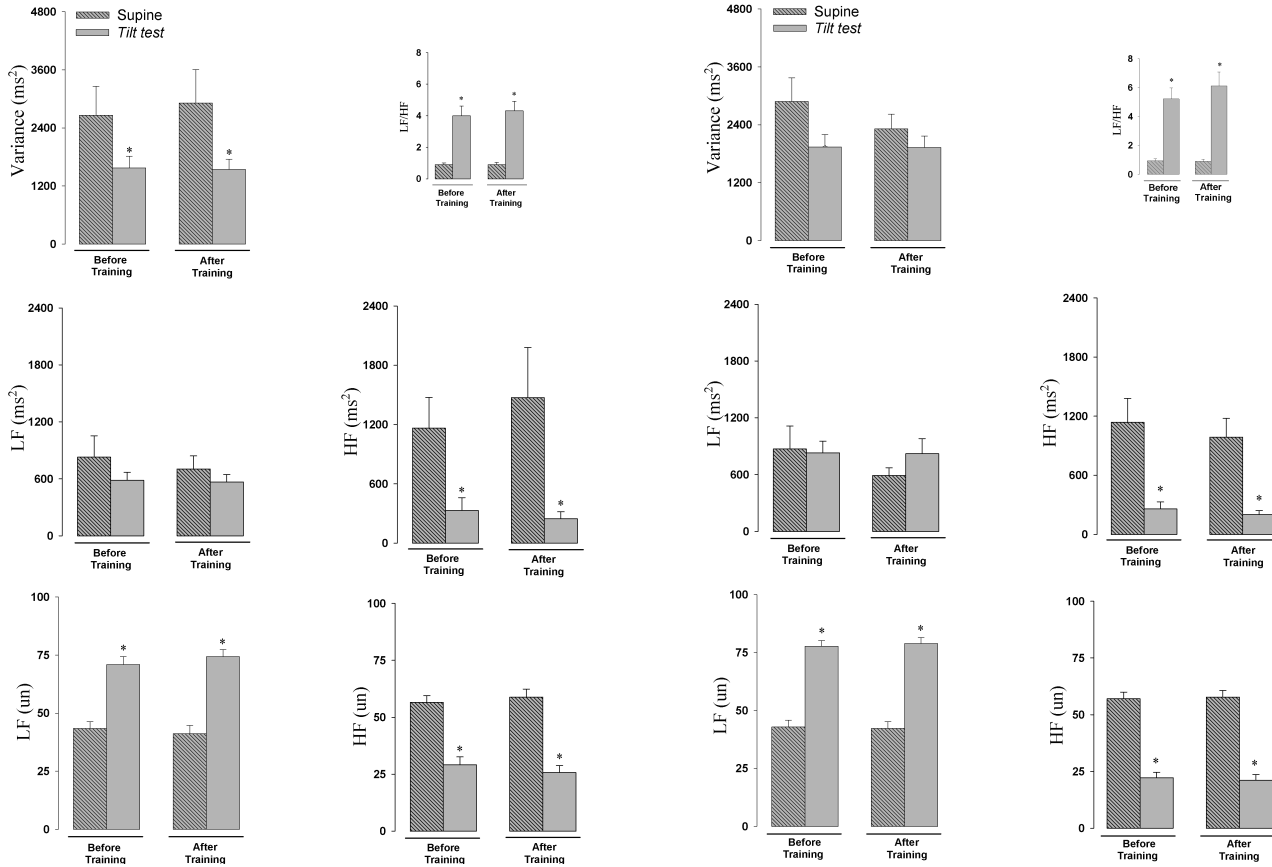

Figure 1. Parameters of spectral analysis of the time series of RR intervals (RRi) obtained in the supine position and during the tilt test in women from the control group (CG) before and after strength training. All values are expressed as means ± S.E.M. *$p<0.05$ compared with the CG in the supine position. HF, high frequency; LF, low frequency; nu, normalized units.

Figure 2. Parameters of spectral analysis of the time series of RR intervals (RRi) obtained in supine position and during the tilt test of women in the polycystic ovary syndrome (PCOS) group before and after the physical strength training. All values are expressed as means ± S.E.M.*$p<0.05$ compared with the PCOS group in the supine position. HF, high frequency; LF, low frequency; nu, normalized units.

Table 3 shows the correlation values between the percentage variations of the LF/HF ratio and the values of the percentage variation of the endocrine-metabolic parameters in the CG and PCOS group, in the supine position and during the tilt test. There was no correlation with any of the variables in both groups in the supine position and during the tilt test for the CG. However, during the tilt test, the PCOS group showed a negative correlation between the percentage variation of the LF/HF ratio and the percentage variation of androstenedione values (p = 0.014), as well as a positive correlation between the percentage variation of the LF/HF ratio and the percentage variation of T/A ratio (p < 0.001).

Table 3. Correlation values between the percentage variations of the LF/HF ratio and the values of the percentage variation of the endocrine-metabolic parameters in the CG and PCOS groups obtained in the supine and orthostatic positions.

	CG (n = 26)		PCOS (n = 27)		CG (n = 26)		PCOS (n = 27)	
	Supine				Tilt test			
	LF/HF				LF/HF			
Endocrine-metabolic values	r	p	R	p	r	p	r	p
Weight, kg	0.314	0.117	0.006	0.973	0.056	0.784	-0.282	0.161
BMI, kg/m^2	0.314	0.117	0.006	0.973	0.056	0.784	-0.282	0.161
Body fat, %	0.292	0.146	-0.009	0.963	0.200	0.324	0.153	0.452
Testosterone, ng/dL	0.113	0.578	-0.032	0.873	0.129	0.526	0.088	0.666
Androstenedione, ng/dL	0.081	0.668	-0.289	0.150	-0.255	0.205	-0.476	0.014
T/A ratio	-0.063	0.756	0.378	0.056	0.305	0.129	0.615	<0.001
SHBG	0.147	0.471	-0.07	0.728	0.272	0.176	0.176	0.386
FAI	-0.069	0.733	0.057	0.779	-0.024	0.904	0.028	0.891
Fasting glucose, mg/dL	-0.159	0.434	0.194	0.339	-0.070	0.731	-0.299	0.136
Fasting insulin, μU/mL	0.307	0.126	-0.077	0.703	0.298	0.138	-0.318	0.112
HOMA-IR, nmol× μU/L	0.344	0.084	-0.012	0.952	0.363	0.068	-0.342	0.087

CG, control group; PCOS, polycystic ovary syndrome; BMI, body mass index; T/A, testosterone/androstenedione; SHBG, sex hormone binding globulin; FAI, free androgen index; bpm, beats per minute; mmHg, millimeters of mercury; kg,kilograms; kg/m^2, kilograms per square meter; %, percentage; ng/dL, nanograms per deciliter; nmol/L, nanomolar per liter; mg/dLmilligrams per deciliter; μU/mL, microunits per liter. *$p < 0.05$.

DISCUSSION

The two main findings of the present study are that women with PCOS presented higher sympathetic cardiac autonomic modulation during the tilt test and higher levels of Testosterone and T/A levels. In addition, strength training was able to reduce testosterone levels and the T/A ratio, however, did not affect cardiac autonomic modulation.

Damage to the cardiac autonomic imbalance is commonly associated with cardio metabolic disorders such as diabetes, hypertension, and metabolic syndrome. Augmented sympathetic tone and reduced HRV are correlated with factors such as increased insulin resistance, hyperandrogenism, increased BMI, vascular alterations, and inflammatory processes (3, 6, 30, 34, 36). In women with PCOS, the risks are even higher because these factors contribute to a vicious cycle that increases androgen production and adipogenesis (7, 41). At the same time, the excess of androgens in women stimulates and promotes an increase in insulin resistance (19, 21, 28, 29).

In our study, the cardiac autonomic modulation assessed by the analysis of HRV in the supine position showed that the two groups had similar behavior, thus corroborating the findings of a recent study (6). However, other studies have reported an increase in the modulation of the sympathetic component in the supine position (34, 45), whereas other authors have reported a reduced HRV in these women (5, 34, 39). In contrast, during the tilt test, both groups showed an increased LF band in normalized units and reduced HF band in absolute and normalized units in the orthostatic position, thus increasing the LF/HF ratio. However, the two groups showed different results in total variance; that is, only the CG showed a significant reduction during the tilt test, both before and after strength training.

Generally, the change of position during the tilt test causes a reduction in the total variance of the spectrum due to the reduction of oscillatory components, which are greater in the supine position and are attributable mainly to the influences of oscillation on the vagal activity present in the HF band (17, 23). The explanation for the no reduction of the total variance in women with PCOS is that, unlike the CG, when the tilt test is applied in the PCOS group, there is greater response in the LF band, with a maintenance tendency or an increase of the LF oscillations in absolute units (ms^2). One of the possible reasons for this finding seems to be related to the increased levels of androgens and insulin (27, 31, 38). In another study, it was demonstrated that men exhibit greater sympathetic modulation than women, probably owing to several factors, including the high serum levels of androgens (8).

In present study, a positive correlation was observed between the LF/HF ratio and the T/A ratio, and a negative relation between the LF/HF ratio and androstenedione. The explanation for such an outcome has not been completely established. However, it is known that a number of factors, including hyperinsulinemia, can lead to an increased secretion of androgens such as androstenedione (7, 25, 28, 29, 31). Thus, androstenedione is then converted into higher testosterone levels, which seem to establish a positive feedback with increased body fat percentage, thus increasing the insulin and testosterone levels and reinforcing the increased insulin resistance (7, 25, 26, 29). However, the reduction on testosterone and T/A ratio levels in the PCOS group after strength training did not cause any changes in the cardiac autonomic modulation, both in the supine and orthostatic positions after the tilt test. These results revealed that other factors may have contributed to the modification of HRV after strength training. One of these factors is the high serum insulin concentrations observed in women of the PCOS group (3, 17, 37), as the literature has shown that high concentrations of insulin have a strong correlation with an increase in visceral fat. In this case, even lean women with PCOS, but with increased visceral fat, would have a greater likelihood of presenting insulin resistance (4, 21, 22). In the present study, women with and without PCOS had similar BMI values and body fat percentages, both before and after strength training. These women were considered to be overweight, and in a few cases, were classified as grade I overweight (12). However, the fact that visceral fat was not quantified in our study is a limiting factor for attributing the effects observed in the HRV to this type of fat, even though the literature has shown that its increase can substantially change the cardiovascular and endocrine-metabolic parameters (4, 21, 22).

In contrast to results, some studies on strength training found a reduction of hyperinsulinemia, which can be explained by some mechanisms that contribute to increasing GLUT4 translocation to the cell surface (2,18). However, studies on the effects of strength training on cardiac autonomic modulation and on hyperinsulinemia are scarce, unlike aerobic training that already has well-established benefits (10, 20, 29, 44).

On the basis of the results obtained, it can be concluded that strength training is satisfactory and relevant in women with PCOS. However, it is suggested the combination with aerobic physical training and dietary intake control to enhance the effects on the metabolism and on the reduction of body fat, thus reducing the risks of cardiovascular and metabolic diseases.

Lastly, the results suggest that strength training was not able to alter HRV autonomic modulation in women with PCOS, however, may reduce testosterone levels and T/A ratio.

The study showed that strength training should be prescribed in the treatment of women with PCOS, as it promotes the improvement of some parameters evaluated, especially related to the androgenic hormonal profile. Future studies should be designed to identify the insulin relationship with the cardiac autonomic control and the role of strength training in other respects, such as its effect on visceral fat and other markers as adipokines and stress oxidative.

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