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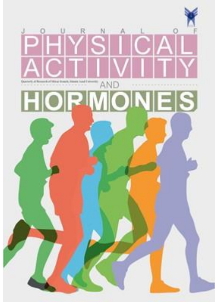

The Effect of Aerobic-Resistance Training on Anti-Mullerian Hormone Levels, Physical Fitness, Body Composition and Ultrasonographic Findings in Women with Polycystic Ovary Syndrome

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Keywords
Polycystic Ovary Syndrome, Anti-Mullerian Hormone, Aerobic-Resistance Training, Physical Fitness, Body Composition.

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Abstract

Introduction: Polycystic Ovary Syndrome (PCOS) is a prevalent endocrine disorder affecting 5-8% of women of reproductive age, often leading to infertility, metabolic disorders, and increased androgen levels. This study investigates the effect of an eight-week aerobic-resistance training exercise training on Anti-Mullerian Hormone (AMH) levels, physical fitness, body composition, and ultrasonographic findings in women with PCOS.

Material & Methods: A quasi-experimental design was implemented with 25 women randomly assigned to either an experimental group (EG, N=13) or a control group (CG, N=12). EG participated in eight-week aerobic resistance training, while the control group maintained regular activity. Pre- and post-intervention measurements were taken for plasma AMH levels, body composition, physical fitness, and ultrasonographic evaluations of ovarian cysts.

Results: This study showed a significant decrease in body weight, body mass index (BMI), and AMH levels, on the other hand, the result showed that improvement in aerobic and anaerobic power in the EG compared to the CG ($P<0.05$), while no significant reduction in ovarian cyst size was observed.

Conclusion: These findings suggest that aerobic-resistance training may contribute to better management of body composition and hormonal levels in women with PCOS, enhancing their overall fitness and potentially improving reproductive outcomes. The study emphasizes the importance of non-pharmacological interventions, such as structured exercise programs, in managing the complex metabolic and reproductive challenges associated with PCOS. Further research is needed to explore the long-term effects of such interventions on ovarian function and fertility outcomes.

1. Introduction

Polycystic Ovary Syndrome (PCOS) is one of the most common endocrine disorders affecting women of reproductive age, with an estimated prevalence ranging between 5%-8%, and characterized by hyperandrogenism, chronic anovulation, and polycystic ovaries. Neuroendocrine alterations in PCOS can be associated with an increased gonadotropin-releasing hormone (GnRH) pulsatility and an increased luteinizing hormone (LH) secretion from the pituitary gland, which results in an elevated androgen synthesis in the ovarian theca cells.(1) PCOS leads to a variety of reproductive, metabolic, and psychological challenges too. Women with PCOS often face infertility due to irregular ovulation, as well as a heightened risk for metabolic disorders such as insulin resistance, obesity, type 2 diabetes, and cardiovascular diseases. Additionally, PCOS is linked to mental health problems, including anxiety, depression, and reduced quality of life, primarily due to the physical and emotional burden of its symptoms. The multifaceted nature of PCOS necessitates a holistic approach to treatment, combining both medical and lifestyle interventions to address its broad spectrum of effects on a woman's health and well-being (2).

Given the complexity of PCOS and its wide-ranging effects, there is a pressing need for non-pharmacological interventions that can effectively manage both the reproductive and metabolic symptoms associated with this condition. According to the Recommendations of the International Evidence-Based Guideline 2023 for the Evaluation and Management of Polycystic Ovary Syndrome, women with PCOS should make lifestyle interventions, such as performing regular exercise or eating a healthy diet combined with exercise to improve the quality of Lifestyle modifications, particularly exercise, have been widely recommended as a primary therapeutic approach(3). Aerobic exercise improves cardiovascular health and metabolic function, while resistance training has been shown to enhance muscle strength and improve body composition. However, despite these benefits, many women with PCOS remain unaware of how structured exercise can significantly alleviate their symptoms. Addressing this knowledge gap is essential, as interventions such as aerobic resistance training can have profound impacts on both hormonal regulation and overall physical fitness, potentially reducing the need for long-term pharmacological treatments.

While exercise has been extensively studied as a therapeutic tool for various metabolic conditions, the specific effects of combined aerobic and resistance training on PCOS-related hormonal imbalances, particularly Anti-Mullerian Hormone (AMH) levels, remain understudied. Some studies have also shown that combined aerobic and resistance exercise is more effective than either aerobic or resistance exercise alone in improving insulin sensitivity, controlling glycemic and reducing abdominal fat in obese women with PCOS(4). On the other hand, some studies reported similar effects of both aerobic and resistance exercises(5) or diet and aerobic exercise interventions(6) on cardiometabolic health markers in women with PCOS. AMH is a critical marker of ovarian reserve and plays a significant role in the pathophysiology of PCOS. Elevated AMH levels in women with PCOS(7) reflect an increased number of small antral follicles, which contributes to the characteristic symptoms of the syndrome. Despite the well-documented metabolic benefits of exercise, there is limited scientific literature that explores the relationship between aerobic-resistance training and changes in AMH levels, as well as other key parameters such as body composition and physical fitness in women with PCOS. This research gap highlights the need for more comprehensive studies that examine how structured exercise programs can influence hormonal markers like AMH and their potential implications for improving fertility and overall health in women with PCOS.

Similar to other non-communicable diseases, physical exercise exerts a protective role in reproductive function and its comorbidities; however, the effects mediated by exercise are largely determined by various factors (e.g., duration and intensity of exercise or the individual overall health status)(1). This study addresses this gap by exploring the novel effects of an eight-week aerobic-resistance training program on AMH levels, physical fitness, body composition, and ultrasonographic findings in women with PCOS. Unlike previous studies that have focused primarily on metabolic outcomes, this research uniquely integrates both reproductive and physical health metrics, offering a more holistic view of how exercise can benefit women with PCOS. The primary objectives of the study are to determine whether aerobic resistance training can reduce AMH levels, improve physical fitness, and modify body composition in women with PCOS, thereby contributing to better reproductive outcomes. By incorporating both aerobic and resistance components, this research provides insight into the combined effects of different exercise modalities on the hormonal and physical challenges associated with PCOS.

2. Methodology

2.1. Materials and methods

This study employed a quasi-experimental design with a pretest-posttest control group to evaluate the effect of an eight-week aerobic-resistance training program on Anti-Mullerian Hormone (AMH) levels, physical fitness, body composition, and ultrasonographic findings in women with Polycystic Ovary Syndrome (PCOS). Participants were randomly assigned to two groups: EG or CG. The study spanned eight weeks, with assessments conducted before and after the intervention. The primary variables examined included AMH levels, body composition indices, physical fitness markers, and sonographic findings related to ovarian cysts.

2.2. Participants

The study recruited a total of 30 eligible women diagnosed with PCOS, aged between 18 and 35 years, from a selected local gynecology clinic. Diagnosis of PCOS was based on the Rotterdam criteria, which requires two out of three of the following conditions: oligomenorrhea or amenorrhea, hyperandrogenism, and the presence of polycystic ovaries observed via ultrasound(8). Exclusion criteria included pregnancy, recent surgical procedures, participation in any regular exercise program within the previous six months, or use of medications that could interfere with hormonal function, such as oral contraceptives, anti-androgens, or insulin-sensitizing agents. The participants were randomly divided into two equal groups. Two women from the experimental group and three women from the control group were excluded. Finally, 13 samples in the EG (aerobic-resistance training) and 12 samples in the CG completed the research period. All participants provided written informed consent after being fully informed of the study's objectives, procedures, and potential risks. Participation was voluntary, and participants were allowed to withdraw from the study at any time without consequence. The study protocol was reviewed and approved by the ethics committee of the Rasht Branch, Islamic Azad University, and all procedures were conducted by the Declaration of Helsinki. Data confidentiality was maintained throughout the study, and all results were reported in aggregate form to ensure participant anonymity. Both groups were matched for baseline characteristics such as age, body mass index (BMI), and PCOS severity to ensure comparability.

2.3. Measurements

Data were collected at baseline (pre-test) and post-intervention (post-test after eight weeks). The following measures were used to assess the outcomes:

2.3.1. Body Composition

Body composition was assessed using multiple indices, including body weight, BMI, waist-to-hip ratio (WHR), and skinfold thickness. These measurements were taken by trained personnel using standardized procedures. Body weight was measured using a digital scale (Beurer, PS160, Germany) with participants in minimal clothing and barefoot. The participants' height was measured in centimeters using a SECA tape stadiometer (model 206, Japan). BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Waist-to-Hip Ratio (WHR) was measured using a tape measure to record waist and hip circumferences, with WHR calculated by dividing waist circumference by hip circumference. Skinfold thickness Measured using calipers at multiple sites (triceps, suprailiac, and thigh) to estimate body fat percentage. Percent body fat (%BF) can be calculated using the Siri equation (% Body Fat = (495 / Body Density) - 450. Body density was calculated using the Jackson & Pollock equation (Body Density = 1.0994921 - (0.0009929 x sum of triceps, thigh, and suprailiac skinfolds) + (0.0000023 x square of the sum of triceps, Thigh, and suprailiac skinfolds) - (0.0001392 x age))

2.3.2. Physical Fitness

Physical fitness was evaluated using aerobic and anaerobic power tests, specifically the Rockport and RAST tests respectively. The VO2 max value serves as an indicator of cardiovascular fitness. Rockport test involved participants walking a mile as quickly as possible, with heart rate and completion time recorded to estimate VO2 max using the Rockport formula(females: VO2 = 139.168 - (0.388 x age) - (0.077 x weight in lb.) - (3.265 x walk time in minutes) - (0.156 x heart rate). The anaerobic power RAST test measured participants' explosive strength and power by timing them as they performed maximal effort sprints or explosive movements. The results were used to assess the participants' anaerobic capacity. Power = Weight × $Distance^2$ ÷ $Time^3$, from the six times, calculate the power for each run and then determine Maximum power (the highest value), Minimum power (the lowest value), and Average power (the sum of all six values ÷ 6).

2.3.3. Anti-Mullerian Hormone (AMH) Levels

AMH levels were measured through venous blood samples taken at baseline and 48 hours after the final training session. Blood samples were collected after an overnight fast (10-12 hours) and were analyzed using an enzyme-linked immunosorbent assay (ELISA) to determine AMH concentrations by a commercial ELISA kit (AMH/MSI ELISA; AnshLabs, TX, USA). The laboratory analyses were conducted at a certified biochemistry laboratory. The AMH results were reported in nanograms per milliliter (ng/mL), with baseline and post-intervention comparisons made to assess the impact of the training regimen on ovarian reserve and hormonal status.

2.3.4. UltraSonographic Findings

Transvaginal ultrasonography was performed on all participants at baseline and after eight weeks to assess changes in ovarian morphology. transvaginal ultrasound examination was performed by the same experienced physician by ultrasonography (Medison, G6000 2MH, FA4, USA) using a vaginal probe of 7 MHz to evaluate each participant’s antral follicle number and OV. Ovaries were scanned from the inner to the outer margin ovaries in both the transverse and sagittal planes. Three dimensions of each ovary were measured, and the total number of antral follicles that were 2–9 mm in diameter were counted. The ultrasound examination focused on ovarian volume, the number of follicles, and the presence or size of ovarian cysts. The criteria for polycystic ovaries included an ovarian volume of more than 9 mL or the presence of 10 or more small cysts measuring 2-8 mm in diameter. The ultrasonographic findings were evaluated by a trained radiologist who was blinded to the participant's group allocation.

2.3.5. Intervention Protocol

The intervention group participated in an eight-week aerobic resistance training program, which included three training sessions per week. Each session lasted 90 minutes, incorporating aerobic exercises, resistance exercises, and recovery periods. The control group was instructed to maintain their usual levels of physical activity and refrain from initiating any structured exercise training during the study period.

2.3.6. Aerobic-Resistance Training Program

The aerobic-resistance training program was designed to combine cardiovascular endurance exercises with strength-building activities. The training protocol consisted of the following phases:

Warm-up (5 minutes): Each session began with 5 minutes of light aerobic activity, such as walking or slow jogging, to prepare the cardiovascular and muscular systems for the upcoming exercise. Stretching exercises were also included to enhance flexibility and reduce injury risk.

Aerobic Training (50 minutes): Participants engaged in rhythmic aerobic exercises, such as treadmill running, cycling, or step aerobics, at 60-70% of their maximum oxygen uptake (VO2 max). The intensity was adjusted for each participant based on their initial fitness levels, with continuous heart rate monitoring to ensure they remained within the target range.

Resistance Training (30 minutes): The resistance training portion involved exercises using body weight, resistance bands, and medicine balls to target the major 8 muscle groups (shoulder flexors, shoulder extensors, shoulder abductors, elbow flexors, elbow extensors, hip flexors, hip extensors, knee flexors, knee extensors, abdominal, and back muscles). Exercises included squats, lunges, push-ups, and core-strengthening movements. Resistance intensity was progressively increased each week to apply the principle of overload. The exercises were performed in sets of 12-15 repetitions, with brief 2-minute rest periods between sets.

Cool-down (5 minutes): The sessions concluded with a cool-down period, consisting of light stretching and deep breathing exercises to promote recovery and reduce muscle stiffness.

All sessions were supervised by a certified exercise physiologist to ensure proper technique and prevent injury. Participants were encouraged to maintain proper hydration and nutrition throughout the program.

2.4. Statistical Methods

Data were analyzed using SPSS software version 21 (IBM, SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize the baseline characteristics of participants, including age, BMI, AMH levels, and fitness measures. Independent t-tests were performed to compare baseline data between the experimental and control groups to ensure no significant differences before the intervention. For the primary outcomes, paired t-tests were used to compare pre- and post-intervention values within each group (e.g., AMH levels, body composition, and physical fitness). Independent t-tests were used to compare changes between the experimental and control groups. A p-value of less than 0.05 was considered statistically significant.

3. Results

The descriptive characteristics of the two groups are presented in Table 1. Since the Kolmogorov-Smirnov test showed a normal distribution of all data, parametric statistics were used for statistical analysis.

Table1. *Description of subjects' characteristics with paired t-test results (compare of pre and post-test)*

Variable	group	Pre-test M±SD	Post-test M±SD	Paired t test	sig
Weight(kg)	EG(n=13)	72.28±8.56	71.02±8.91	2.50	.028*
	CG(n=12)	68.79±7.84	69.06±8.03	-1.80	.099
BMI(kg/m^2)	EG(n=13)	27.88±4.21	27.40±4.39	5.35	.001*
	CG(n=12)	27.08±4	27.18±4.05	-1.71.	.115
Fat%	EG(n=13)	37.30±5.10	36.92±4.96	3.13	.003*
	CG(n=12)	36.90±4.84	36.90±4.90	.02	1.00
WHR ratio	EG(n=13)	.80±.05	.80±.05	1.09	.294
	CG(n=12)	.81±.13	.79±.13	-1.71	.797
AMH(ng/ml)	EG(n=13)	6.63±2.64	5.13±2.39	5.14	.001*
	CG(n=12)	5.40±2.86	5.64±3.06	1.115	.27
Ovarian cyst size(mm)	EG(n=13)	28.92±3.56	28.46±3.88	3.14	.053
	CG(n=12)	27.83±4.15	27.91±3.94	-.56	.58
Aerobic power (min/kg/ml)	EG(n=13)	24.15±3.30	27±2.25	-6.75	.001*
	CG(n=12)	24.63±3.36	24.55±3.49	1.00	.339
Anaerobic power (Watt)	EG(n=13)	171.15±10.07	182.07±9.61	3.82	.002*
	CG(n=12)	172.91±8.28	173±7.85	-.36	.72

AMH: Anti-Mullerian Hormone, WHR: waist-to-hip ratio,*: p < .05

Compared to the pre-test, the results of statistical analysis showed that exercise training in the experimental group in the post-test resulted in a significant reduction in weight, fat percent, BMI, and AMH, and an increase in aerobic and anaerobic power.

Considering the statistical results of the independent t-test between groups in the pre-test, which indicated a lack of statistical significance between the variables, the results of the inter-group comparison in the post-test were presented in Table 2.

Table 2. *Independent t-test between EG and CG group in the posttest*

variable	Means difference	F	t	sig
Weight(kg)	1.71	1.78	3.24	.004*
BMI(kg/m^2	.57	1.43	2.78	.012*
Fat%	.74	3.57	1.87	.08
WHR ratio	.003	.695	-.77	.44
AMH(ng/ml)	.264	1.54	4.80	.001*
Ovarian cyst size(mm)	1.08	4.86	2.04	.052
Aerobic power(min/kg/ml)	2.45	4.04	2.10	.04*
Anaerobic power(Watt)	9.07	.002	2.57	.01*

AMH: Anti-Mullerian Hormone, WHR: waist-to-hip ratio,*: p < .05

In the post-test, a significant decrease in weight, body mass index, AMH, and an improvement in aerobic and anaerobic power were observed in the EG compared to the CG. There were no differences in other variables.

4. Discussion

Our study showed a reduction in weight, body mass index, and serum anti-Mullerian hormone levels in women with ovarian cysts who underwent strength-endurance exercise training, accompanied by improvements in their aerobic and anaerobic fitness.

The significant reduction in body weight and body mass index (BMI) observed in the experimental group underscores the benefits of combined aerobic and resistance training in managing obesity and metabolic dysfunction in women with PCOS. Weight management is critical in PCOS because excess weight, particularly abdominal obesity, is associated with insulin resistance, hyperandrogenism, and an increased risk of cardiovascular disease(9). The improvements in body composition in the experimental group are particularly notable given the stable body weight and BMI in the control group, which did not undergo any structured exercise intervention. A systematic review and meta-analysis showed that there was moderate certainty that aerobic exercise (10–32 weeks in duration) lowers BMI. As excess body weight can aggravate the underlying hormonal disturbances (such as increased levels of androgens and risk factors for cardiovascular disease and diabetes, this is an important clinical finding. Overall, these results serve to reaffirm the importance of exercise as a non-pharmacologic management strategy for the reduction of known risk factors for women with PCOS(10). During aerobic exercise, the biochemical adaptations trigger a series of physiological stimuli that increase the oxygen uptake and oxidation of free fatty acids and circulate glucose as an energy source(11). In this way, aerobic metabolism is potentially increased to supply the energy required by muscle contractions, reducing body fat deposits, decreasing obesity rates, and improving cardiorespiratory fitness (12).

The reproductive functions of women with PCOS can be improved with physical activity(13). Interventions that target insulin sensitivity, and for women with obesity, and

PCOS, promote weight loss are critical in the management of the condition(14). Recent research indicates that exercise of moderate intensity (~50-70% VO2max), for approximately 12 weeks, produces improvement in cardiometabolic risk factors, including blood pressure, TG, insulin resistance and inflammation, and reproductive outcomes such as increased ovulation rates and greater responsiveness to IVF(15). The biggest challenge in weight management programs is to achieve a reasonable and sustainable weight loss (16). The participants with increased menstrual cycle regularity had hyperandrogenism (PCOS phenotype A/B), and overweight or obesity; 50% lost weight during the intervention. This finding raises two questions: the response to exercise is probably related to PCOS phenotype (are phenotypes with hyperandrogenism more responsive to exercise); and the reproductive responses to exercise vary by baseline BMI and/or weight loss(17).

Our findings align with limited research that has suggested exercise may modulate AMH levels(18). Lifestyle factors are associated with differences in AMH levels and thus should be taken into account when interpreting individual AMH measurements. Furthermore, AMH levels can be influenced by the alteration of lifestyle behaviors. While this can be a helpful tool for clinical and lifestyle counseling, the nature of the relation between the observed differences in AMH and the true ovarian reserve remains to be assessed. Increased serum AMH may be used as a marker of ovulatory dysfunction and hyperandrogenism but not as a marker of insulin resistance (19). Three-component (physical activity, nutrition and counseling) lifestyle interventions seem to have the biggest effect, compared to one or two components (20). Possible factors that are responsible for obtaining the expected response of exercise include genes, age, and hormonal status of the individual. Lifestyle changes, including physical activity modification, can be recommended as an early management strategy to reduce PCOS-related comorbidities, as it decreases insulin resistance, enhances metabolic and reproductive characteristics, and enhances self-esteem (21). However, despite these positive outcomes, no significant change in ovarian cyst size or count was observed in the ultrasonographic findings. This is consistent with some previous studies, which have also reported that short-term exercise interventions, while beneficial for metabolic and hormonal health, do not necessarily lead to changes in the structural characteristics of the ovaries. Changes in ovarian morphology may require longer intervention periods or more intensive treatments to manifest. Therefore, future research should explore whether prolonged or more intensive exercise regimens can impact ovarian cyst size and number over time. There is a large number of small (one or two-component) studies demonstrating that losing 5 to 10% of initial body weight improves reproductive, metabolic, and psychological features in PCOS women(22). Incorporating a healthy diet, increasing physical activity, and changing dysfunctional thinking patterns in women with PCOS are key points in losing weight(23). Nasiri et al found reductions in weight, Fat%, visceral adipose tissue, WHR, and BMI in combined endurance and resistance exercise group, saying that resistant workouts in combination with aerobic training can lead to advantages in some anthropometric indices in women with PCOS (24).

Physical fitness, as measured by VO_{2max} and anaerobic power, improved significantly in the experimental group, reflecting enhanced aerobic capacity and cardiovascular health. This is a critical outcome, as women with PCOS are at increased risk for cardiovascular disease due to associated metabolic abnormalities, such as insulin resistance, dyslipidemia, and obesity. The improvement in VO2 max suggests that regular aerobic-resistance training can mitigate some of these risks by improving cardiovascular endurance and metabolic health. Thomson et al. showed that Compared to age- and weight-matched healthy overweight and obese women with similar insulin resistance and CVD risk profiles, women with PCOS had similar aerobic capacity and muscle strength. This suggests PCOS, at least without an adverse metabolic profile is unlikely to limit physical function(25). A study revealed that both high-intensity intermittent training (HIIT) and combined (COM) training could be beneficial in improving some anthropometric indices in addition to aerobic capacity (24). Two recent works on overweight and PCOS women reported significantly decreased amounts of VO_{2max} than healthy controls. A study by Patten et al.(26), suggested that exercises can improve VO_2 max in this population. In addition, recent evidence showed that resistance training in young and elderly individuals led to an elevation in VO_{2max} (27). Decreased VO_{2max} seems to be caused naturally by age; however, inactivity is its main reason. Further studies are warranted to investigate the long-term impact of exercise on ovarian morphology and reproductive health, but these results support the role of non-pharmacological interventions in improving both metabolic and reproductive outcomes in women with PCOS. The sample size was relatively small, and the duration of the intervention was limited to eight weeks, which may not fully capture the long-term effects of exercise on hormonal and metabolic parameters in women with PCOS. Future studies should aim to include larger and more diverse populations and extend the duration of the intervention to assess the sustainability of exercise benefits over time. The findings underscore the importance of lifestyle modifications in managing PCOS and support the integration of structured exercise into routine care for affected women.

5. Conclusion

The findings of this research showed that concurrent resistance aerobic exercises improve body composition (weight and BMI), increase $VO2_{max}$, and decrease plasma AMH hormones. No significant reduction in ovarian cyst size was observed. The reduction in AMH and enhancement in fitness suggest that regular structured exercise may contribute to better management of PCOS symptoms and overall health.

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Conflict of interests: The authors declare that they have no conflict of interest relating to the publication of this manuscript.

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