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Effect of whole-body vibration on insulin resistance in females with polycystic ovarian syndrome: A randomized controlled trial

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Abstract

Introduction

Polycystic ovarian syndrome (PCOS) is prevalent in females, impacting their health and their life quality. Therefore, this study aimed to investigate the effect of adding whole-body vibration (WBV) to the traditional treatment of polycystic ovarian syndrome.

Material and methods

Forty-six females diagnosed with PCOS. Their ages 20 to 35 years, with a body mass index (BMI) of 25-29.9 kg/m²; were randomly divided into two equal groups: The study group followed an iso-caloric, low-glycemic diet and performed aerobic exercises in addition to WBV and the control group followed an iso-caloric, low-glycemic diet and performed aerobic exercise only (n = 23 each). Treatment lasted for 8 weeks, sessions per week. BMI, waist-hip ratio (WHR), and LH/FSH ratio were assessed pre- and post- treatment. Insulin resistance was assessed by HOMA-IR (Homeostatic Model Assessment for Insulin Resistance) pre- and post-treatment.

Results

Weight, BMI, HOMA-IR, and LH/FSH ratio showed a statistically significant decrease when comparing before to after-treatment in both groups (p < 0.05). However, WHR showed a statistically significant decrease only in the study group (p < 0.05). Compared to the control group, the study group showed a significant reduction in weight (-8.08 kg vs. -4.39 kg, p = 0.0009), BMI (-2.99 kg/m² vs. -1.6 kg/m², p = 0.004), WHR (-0.05 vs. -0.018, p = 0.009), HOMA-IR (-1.54 vs. -0.77, p = 0.03), and LH/FSH ratio (-0.53 vs. -0.5, p = 0.02) after 8 weeks of treatment.

Conclusions

This study reveals the favorable outcomes of adding WBV to aerobic exercise for females with PCOS.

Keywords: Polycystic ovary syndrome, Vibration, Exercise, Insulin

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Introduction

Polycystic ovary syndrome (PCOS) is women's top-ranking condition affecting endocrine function, with rates ranging from 4% to 20% [1-2]. The precise origins of this condition remain largely undetermined; however, insulin resistance (IR) is posited as a primary mechanism contributing to PCOS, with about 75% of individuals diagnosed with PCOS exhibiting IR [3]. In theory, PCOS is believed to result from a cycle in which an excess of androgens encourages the accumulation of fat around the abdomen and visceral organs, producing IR and increased insulin levels. This, in turn, stimulates the ovaries and adrenal glands to produce higher levels of androgens. This pathological cycle, involving IR, excessive insulin production, and elevated androgen levels, coupled with dysfunction in the hypothalamic-pituitary axis, culminates in further ovarian impairment, potentially causing anovulation and infertility [4,5]. Additionally, it is associated with long-term metabolic conditions like type 2 diabetes mellitus, heart-related diseases, mood disturbances, and disordered eating, which in turn lower women's quality of life [6].

Conventional treatments for PCOS have primarily targeted fertility issues and hormonal regulation. However, IR is a key factor in the underlying etiology of this condition. Addressing this factor has demonstrated remarkable efficacy in certain clinical scenarios, diminishing the reliance on expensive assisted reproductive methods [7]. Lifestyle modification (dietary and exercise interventions) constitutes the primary therapeutic approach for PCOS in women. Diets with a low glycemic index (GI), as opposed to those with a high GI, have been linked to improvements in IR measured by HOMA-IR, fasting insulin, fasting glucose, and the free androgen index. They also decreased total and low-density lipoprotein (LDL) cholesterol, triglycerides, waist circumference, and total testosterone, while leaving weight and HDL cholesterol unchanged [8].

Regular exercise has been known to enhance insulin sensitivity. However, metabolic syndrome patients find it challenging to stick to traditional exercise because of their higher body mass, musculoskeletal restrictions, decreased physical fitness brought on by time constraints, and diminished motivation. Whole-body vibration exercise (WBVE) may be a helpful alternative for managing patients to overcome these restrictions [9].

WBV represents a contemporary method that involves the use of specific frequency and amplitude settings within safe ranges, carried out on a designated platform. Evidence supports WBV's effectiveness in enhancing muscular strength and flexibility, intensifying neurological stimulation, improving blood flow, and reducing pain perception and friction caused by different types of tissue, which promotes faster tissue healing and tendon and bone strength. It takes less training time and movement execution than traditional exercise [10].

Multiple studies and systematic reviews show that WBVE has successfully improved body fat mass among women after menopause [11]. Also, Deng [12], investigated how a WBVE training program affected obese college students, finding that they had lower body fat percentages. Additionally, Reis-Silva et al. [13] Click or tap here to enter text. found that patients with metabolic syndrome improved in body composition and decreased waist circumference after completing the WBVE program for six weeks. Additionally, Liu et al. [14] reported that WBV administration is a promising treatment for individuals who suffer from central obesity and IR. However, to our knowledge, there is no study investigating its effect on females with PCOS.

Also, as known WBV takes less training time and movement execution than traditional exercise [10] which could help females with PCOS overcome their most reported barriers which are fatigue and lack of time, fear of injury, and physical limitations as reported by Banting et al. [15]. Finding a way that address these barriers while improving their condition is crucial. To our knowledge, this study is the first study that investigates the effect of WBV on IR in PCOS females. We hypothesized that WBVE could be a time-efficient solution that addresses these barriers while decreasing IR which is considered the root cause of PCOS. Therefore, this study aimed to investigate the effect of WBV on IR in females with PCOS.

Materials and methods

Study design

The design of this study was a randomized, controlled clinical trial.

Ethics approval statement

Before starting, the study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University (No: P.T.REC/012/003460). It followed the CONSORT statement and the guidelines of the Declaration of Helsinki for conducting human research. The study was conducted from March 2022 to October 2023. Participants were enlightened about the study's objectives, nature, and benefits, emphasizing their freedom to discontinue participation at any time without giving reasons. Each participant was required to sign a written form of consent before starting the study. The study was registered at the Clinical Trials Registry (Registry ID: NCT05215223).

Recruitment and Randomization

Out of fifty-five women referred by a gynecologist with PCOS, nine were disqualified from participation; this included four who declined to participate and five who did not meet the inclusion criteria. Therefore, forty-six female subjects joined the study and were allocated randomly to two groups by a computer-generated block randomization program (Figure 1).

To be enrolled, females ought to be (1) Virgins; (2) Diagnosed with PCOS by a gynecologist according to Rotterdam PCOS diagnostic criteria; (3) Their HOMA-IR was more than 2.5 (4) Their LH/FSH ratio was more than 1 (5) Sedentary, not engaged in physical training for the previous three months before the study, (A weekly physical activity of < 600 MET minutes/week, per the international physical activity questionnaire); (6) Their ages varied from 20 to 35 years, (7) With a BMI of 25-29.9 kg/m², and (8) Having a stable body weight / not following a diet plan for weight loss for the previous three months [16,17].

Females were excluded if (1) They presented with any cardiometabolic conditions (such as hypertension, diabetes mellitus, or cardiovascular diseases), cancers, or other endocrine disturbances (for example, hyperprolactinemia or hypothyroidism), or abnormalities in the adrenal glands; (2) had received hormonal therapies in the three months preceding the study; (3) had undergone any other treatments related to PCOS and/or (4) were using weight loss medications (like orlistat).

Participants were questioned about their menstrual history, covering aspects like cycle frequency, duration, amount, and regularity, as well as any medical or hormone-based therapies undertaken in the previous six months. Data was recorded in a data-collecting sheet.

Random assignment of patients was carried out using the Statistical Package for Social Sciences (SPSS) for Windows, version 25, developed by SPSS, Inc, in Chicago, IL. The randomization codes were securely stored in locked, non-transparent envelopes with sequence numbers to achieve allocation concealment. Randomization was performed by an evaluator who had no involvement in either the evaluation or therapeutic interventions. Forty-six PCOS females were randomly assigned into either a control group, who received diet + aerobic exercise (n = 23), or a study group, the diet + aerobic exercise + WBV group (n = 23). None of the participants exited the study after being randomized.

Once randomized, those in the control group adhered to an iso-caloric low-glycemic diet. They performed moderate-intensity aerobic exercise for three weekly sessions for eight weeks. In contrast, those in the study group received the same iso-caloric low-glycemic diet and aerobic

exercise as the control group, along with WBV for three weekly sessions for eight weeks. Qualified physical therapists administered both aerobic exercise and WBV sessions are shown in Table 1.

Tab. 1. Schedule of enrollment, intervention, and assessment (SPIRIT).

Participant characteristics	Enrollment	Allocation	T1	T2
Inclusion and exclusion criteria	X			
Age		X		
Assessment				
Homa IR			X	X
Weight & BMI			X	X
WHR			X	X
FSH/LH Ratio			X	X
Interventions				
Iso-caloric low glycemic diet			▬	
Aerobic exercise			▬	
WBV			▬	

SPIRIT- Standard Protocol Item: Recommendations for Interventional Trials, T1- pre-treatment assessment, T2- post-treatment assessment

Once baseline measurements were taken, the process of opening the envelopes commenced, and treatment was continued in consistency with the minimum proper sample size for the current study, identified as 23 females per group. Both groups received an iso-caloric low glycemic diet and performed moderate-intensity aerobic treadmill walking thrice weekly for eight weeks.

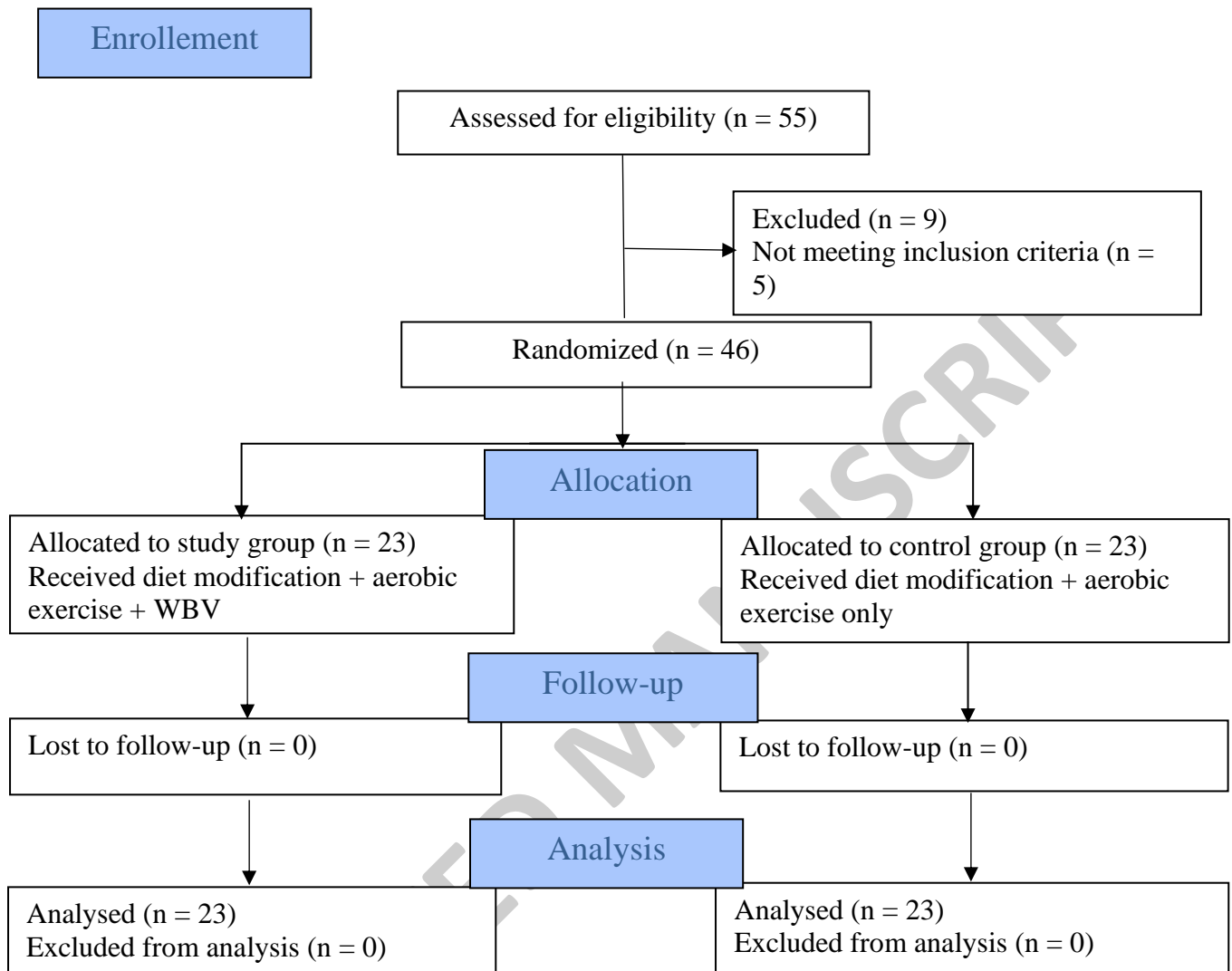


Fig. 1. Flow chart of the study

Assessment

HOMA-IR (Primary outcome)

A blood draw was conducted after participants fasted overnight for eight hours. Plasma glucose concentrations were determined employing the hexokinase enzyme reference technique. Fasting insulin levels were quantified through a radioimmunoassay (RIA) procedure (Coat A Count Insulin, Los Angeles, USA). To assess IR, HOMA-IR was utilized (fasting serum insulin ($\mu\text{U/ml}$) \times fasting plasma glucose (mmol l^{-1})/22.5) [18]. A proxy measure of insulin resistance (IR) based on the correlation between fasting glucose and insulin levels is the homeostasis model assessment of insulin resistance (HOMA-IR), where higher HOMA-IR values indicate more

severe IR [19]. HOMA-IR and 1/HOMA-IR are reliable estimates of clamp-derived insulin sensitivity [20].

Body weight and BMI (secondary outcome)

Body weight was assessed at the beginning and end of the study for all participants, using a calibrated weight-height scale. Patients were instructed to stand upright on the scale, facing forward, dressed in lightweight clothing, and without shoes, allowing for the simultaneous measurement of weight and height. Subsequently, the BMI for each female was calculated using the following equation: $BMI = \text{Weight} / \text{square of height (kg/m}^2\text{)}$. The BMI, or wt/ht^2 , is a valid and reliable indicator of obesity [21]. It is an acceptable and valid indicator of the risk of overweight and the presence of overweight [22].

Waist-hip ratio (WHR) (secondary outcome)

Waist circumference was assessed by positioning a tape measure midway between the lower rib margin and the iliac crests horizontally. Hip circumference was assessed at the widest part of the buttocks. Two measurements to the nearest 0.5 were taken for each waist and hip circumference. WHR was derived by taking the mean waist circumference and dividing it by the mean hip circumference [23]. Waist circumference is a simple, inexpensive method for teaching individuals to take their body circumferences and provides reliable and valid accurate data [24].

FSH/LH ratio (secondary outcome)

After an eight-hour fast, baseline LH and FSH were assessed using an electro-chemiluminescence immune assay (ECLIA). The serum, upon separation, should be stored frozen before assay [25]. Samples from all participants were processed through the same analytical test to reduce variability between assays. LH/FSH ratio, which is a more accurate and valid indicator of ovarian reserve than either FSH or LH [26].

Interventions

The study group participants underwent (Diet modifications + aerobic exercise + WBV), whereas the control group participants underwent (Diet modifications + aerobic exercise only).

Iso-caloric Low glycemic index diet

Once a female was eligible to participate, a nutritionist scheduled an appointment to create a tailored dietary plan for each participant. This plan was formulated considering the individual's dietary preferences, caloric needs, and eating patterns to improve adherence to the diet and provide a thorough explanation of its components. The dietary strategy aimed to maintain the participants' customary intake of energy and macronutrients through an isocaloric approach. The diet depends on replacing high-GI and medium-GI foods with low-GI alternatives, using a system of equivalent exchanges, such as replacing white bread with wholegrain bread. They were advised to include unsaturated fats from sources like olive oil, avocado, seeds, and nuts while moderating overall fat consumption. They were instructed to increase their vegetable and salad intake while minimizing their added sugar consumption [27]. The dietitian followed up with the patients through weekly counseling visits.

Moderate-intensity aerobic exercise

Females in both groups performed a supervised moderate-intensity aerobic exercise on the treadmill (SCIFIT, AC5000, USA) for 45 minutes /session and three sessions/week for eight weeks. First, each female's age was subtracted from 220 to determine her maximum heart rate. Then, exercise intensity was determined to be 60% to 70% of each female's maximal heart rate (HRmax) [28]. Each session is divided into three parts: the warm-up, the active phase, and the cool-down. The warm-up phase lasted 5 minutes. The active phase lasted 35 minutes, gradually increasing the speed to reach 70% HRmax. Then, there was a cool-down phase for 5 minutes.

Whole body vibration exercise

Group B females participated in WBV exercise sessions on a side-to-side oscillating WBV platform (JFF002C, China). They were standing barefoot in the center of the WBV platform while maintaining a squat with 60-degree knee flexion and an extended trunk. To minimize vibration transfer to the head, WBV sessions should be conducted with slightly bent knees, ensuring short durations, low frequencies, and minimal amplitudes. Prolonged exposure to vibrations can cause muscle fatigue, muscle contraction force reductions, nerve conduction velocity, and attenuated perception. Additionally, high-vibration transmission frequencies can induce symptoms similar to motion sickness in some individuals [29]. Therefore, the first training session included three 1-minute WBV sets, with 1-minute standing breaks in between. The amplitude of the vibration was adjusted at 1 mm. Subsequently, an additional set was introduced in each session until a total of

ten WBV sets were achieved. The frequency was adjusted to 14 Hz, a level known to elicit muscular activation while avoiding negative consequences [29]. The WBV training sessions were conducted thrice weekly for a total of eight weeks.

Calculating the size of the sample

Before starting the trial, the pilot study results were used to calculate the sample size of ten patients, five in each group. F tests, MANOVA, repeated measures, and within and between-interaction analysis were used on the primary outcome variable (HOMA IR) to calculate an effect size of 0.35. The alpha levels were set at 0.05 and $\beta = 0.2$. The sample size was supposed to be 36 based on these criteria; however, because of dropouts, the final number was increased by 25 % to 46 patients. G*POWER (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) statistical software was used for calculation.

Statistical analysis

All outcome measures demonstrated normal distribution using the Shapiro-Wilk test, which assessed each measure's normality. The physical characteristics of patients in the form of age and height were compared using an unpaired t-test. Chi-square (X^2) and Fisher exact tests were used to compare both groups concerning menstrual history in frequency, regularity, amounts of pads, and dysmenorrhea. A mixed multivariate analysis of variance (MANOVA) was used to investigate the influences of the treatments (groups), the factor of time, and the interaction between group and time. When the MANOVA found statistically significant effects, a follow-up univariate ANOVA was conducted. Bonferroni correction was used for multiple pairwise comparisons to avoid type 1 errors. To assess how much there were variations across groups, a partial eta square (η) was utilized. The IBM Corp. (IBM Corp., New York, USA) SPSS version 23 was used for all analyses.

Results

Table 2 shows the subject characteristics of both groups. The unpaired t-test and Chi-square reported statistically insignificant differences between both groups.

Tab. 2. Patient's physical characteristics

	Study group Mean \pm SD	Control group Mean \pm SD	T-value	p-value
Age (years)	27.86 \pm 3.88	27.56 \pm 4.14	- 0.92	0.36a
Height (m)	1.64 \pm 0.04	1.65 \pm 0.03	0.25	0.79a
Menstrual frequency (oligomenorrhea/normal/amenorrhea)	19 oligomenorrhea / 4 normal/ 0 amenorrhea	17 oligomenorrhea / 6 normal/ 0 amenorrhea		0.72a
Menstrual regularity (regular/irregular)	3 regular/ 20 irregular	5 regular/ 18 irregular	X ² = 0.61	0.43a
Amounts of pad per day (average/heavy/mild)	9 average/ 14 heavy/ 0 mild	10 average/ 13 heavy/ 0 mild		0.77a
Dysmenorrhea (mild/moderate/severe)	5 mild/ 10 moderate/ 9 severe	6 mild/ 8 moderate/ 9 severe	X ² = 0.37	0.83a

^a - no significance difference, m- meter, p-value- significance level, SD- standard deviation, X²- Chi-square

Table 3 shows within and between group analysis. MANOVA indicated a statistically significant difference between groups as Wilks' Lambda (Λ) = 0.52, $f = 5.08$, $p = 0.0001$, and $\eta^2 = 0.48$. In addition, there was a significant difference at a time as $\lambda = 0.02$, $f = 235.1$, $p = 0.0001$, and $\eta^2 = 0.97$. Finally, there was a significant interaction between group and time as $\lambda = 0.16$, $f = 28.28$, $p = 0.0001$, and $\eta^2 = 0.84$.

Multiple pairwise comparisons revealed statistically significant differences for all variables across the timeline from before to after treatment in both groups except the WHR in the control group. Comparative group analysis prior to treatment demonstrated statistically insignificant differences. However, there were statistically significant differences in post-treatment between both groups in all variables, which was more favorable to the study group.

Tab. 3. Within and between group analysis

Variables	Study group	Control group	p-value (between groups)	F-value (between groups)	η^2
Weight (KG)					
Pre-treatment	77.39 \pm 5.43	77.56 \pm 4.3	0.9a	0.01	
Post-treatment	69.3 \pm 5.41	73.18 \pm 4.01	0.0009b	7.59	0.15

p-value (within-group)	0.0001b	0.0001b			
MD (95% CI)	8.08 (7.48 to 8.69)	4.39 (3.78 to 4.99)			
% of improvement	10.4 %	5.6 %			
BMI (kg/m ²)					
Pre-treatment	28.62 ± 1.14	28.37 ± 1.13	0.46b	0.54	
Post-treatment	25.62 ± 1.34	26.77 ± 1.18	0.004b	9.36	0.18
p-value (within-group)	0.0001b	0.0001b			
MD (95% CI)	2.99 (2.78 to 3.2)	1.6 (1.39 to 1.8)			
% of improvement	10.5 %	5.6 %			
WHR					
Pre-treatment	0.8 ± 0.04	0.81 ± 0.05	0.49a	0.48	
Post-treatment	0.75 ± 0.05	0.79 ± 0.04	0.009b	7.48	0.5
p-value (within-group)	0.0001b	0.09a			
MD (95% CI)	0.05 (0.03 to 0.07)	0.018 (0.003 to 0.03)			
% of improvement	6.2 %	2.2 %			
HOMA-IR					
Pre-treatment	4.13 ± 0.87	3.97 ± 1.02	0.58a	0.31	
Post-treatment	2.58 ± 0.42	3.19 ± 0.8	0.03b	4.7	0.09
p-value (within-group)	0.0001b	0.0001b			
MD (95% CI)	1.54 (1.4 to 1.69)	0.77 (0.63 to 0.92)			
% of improvement	37.2 %	19.4 %			
LH/FSH ratio					
Pre-treatment	1.95 ± 0.32	2.32 ± 0.53	0.18a	1.87	
Post-treatment	1.41 ± 0.44	1.81 ± 0.68	0.02b	5.63	0.11
p-value (within-group)	0.0001b	0.001b			
MD (95% CI)	0.53 (0.28 to 0.79)	0.5 (0.24 to 0.76)			
% of improvement	27.2 %	21.5 %			

^a- no significance difference, ^b- significant difference, CI- confidence interval, F-value- variance of group means/mean of the within-group variance, FSH- follicle stimulating hormone; HOMA IR- homeostatic model assessment for insulin resistance; LH- luteinizing hormone; MD- mean difference; η^2 - partial eta square, p-value- significance level, SD- standard deviation, WHR- waist-hip ratio

Discussion

This study aimed to investigate the effect of adding whole-body vibration (WBV) to the traditional treatment of polycystic ovarian syndrome. The results revealed a statistically significant decrease in weight, BMI, LH/FSH ratio, and HOMA-IR in both groups when comparing post-treatment to pre-treatment. However, WHR decreased significantly only in the study group. The post-treatment comparison revealed that there is a statistically significant difference between both groups, favoring the study group. These results showed the effectiveness of WBV as an intervention method to improve insulin resistance and the hormonal status of females with PCOS.

Regarding weight and BMI, our results are supported by Vissers et al. [30] who concluded that incorporating an energy-restricted diet alongside aerobic training or WBV sessions can effectively facilitate a prolonged 5 to 10 percent decrease in overall weight. Recent findings demonstrate a reduction in the accumulation of body fats in Fischer rats due to WBV [31]. Also, our results come in alignment with Wilms et al. [32] who found that patients undergoing WBVT experienced a greater reduction in BMI compared to those who participated in a program of aerobic exercises and dieting. Moreover, Milanese et al. [33] demonstrated that adding two WBV sessions per week to a typical lifestyle for approximately ten weeks decreased body BMI. Also, Kite et al. [34] suggested that exercise combined with diet for a brief period could help lower BMI in female PCOS patients.

However, in contrast with our findings, Rubin et al. [35] found that quick, daily sessions of light mechanical stimulation through WBV can hinder adipogenesis within the murine subjects. Additionally, Roelants et al. [36] discovered that while WBV slightly increased lean body mass, it failed to diminish weight, overall body fat, or subcutaneous fat among females lacking prior training. This difference in results may be due to the difference in the population and the dose of vibration.

Regarding WHR, our findings revealed that there was a statistically significant decrease in the study group only. This is reinforced by Vissers et al. [30] who indicated that WBV training, when integrated with a diet low in calories, could potentially lower waist circumference, WHR, and VAT more effectively than aerobic exercise. This is supported by Huang et al. [37] study, which concluded that whole-body vibration reduces body fat.

These findings regarding the decrease in weight, BMI, and WHR can be explained by research conducted by Ando and Noguchi [38] as they found that acute WBV exposure triggers sweating in the palms and stimulates the central sympathetic nervous system. Additionally, Thorp and Schlaich's [39] review revealed that the sympathetic nervous system can initiate the breakdown of fat. They explored a link between the diminished activity of the sympathetic nervous system and reduced rates of fat oxidation, determining that decreased activity within the sympathetic nervous

system can elevate obesity risk. Furthermore, Prisby et al. [40] found that the overall impact of WBV on body fat might be influenced by a range of systems, involving the endocrine, musculoskeletal, nervous, and circulatory systems.

Regarding the LH/FSH ratio, the post-treatment comparison revealed that there was a significant statistical decrease in the LH/FSH ratio favoring the study group. This result may be supported by Ruffing et al. [41] who investigated the effect of short-duration dietary and exercise programs on LH pulse and WBV is considered as a type of exercise. They found a decrease in LH pulse frequency however, they stated that the mechanism is unknown yet. We propose that the mechanism may be due to improved psychological status, as aerobic exercise and WBV training have proven to improve psychological status and mood, and this regulates the body's hormones [42]. To our knowledge, there is no study investigating the effect of WBV on the LH/FSH ratio so further studies are needed.

Regarding insulin resistance, our results revealed that there was a statistically significant decrease in HOMA-IR in both groups. However, post-treatment comparison revealed that there was a statistically significant difference between both groups in favor of the study group. These results are supported by previous research as moderate-intensity aerobic exercises can also enhance hepatic glucose production and lipid metabolism, reducing IR and improving the overall quality of life for individuals with PCOS [31, 35]. Since, to our knowledge, there are no studies investigating the effect of WBV on IR in females with PCOS, further studies are needed.

The mechanism by which whole-body vibration (WBV) exercise has a favorable effect on insulin resistance (IR) may be attributed to the neurogenic enhancement and muscular activation caused by WBV stimuli, which results in functional and structural tissue adaptations over time as these mechanical vibrations that increase blood flow and circulation by stimulating muscular contractions as described by Cardinale and Bosco [43]. Consequently, an improvement in muscle glucose absorption and a decrease in IR are observed. Studies also have demonstrated that WBV exercise enhances oxygen consumption, fat-burning rates, and calorie burning, which could positively affect adipose tissue and improve IR[30,44,45]. Furthermore, this improvement in insulin sensitivity may also be due to increased adiponectin, a protein known to correlate well with insulin sensitivity [46].

Strengths and limitation

During the course of the study, no negative outcomes were observed. WBV might be viewed as a potential treatment option for PCOS women. However, this research comes with

certain constraints that warrant attention as there is no follow-up for the patient so additional research is essential to assess the lasting impacts of WBV.

Clinical implications

Females suffering from PCOS could find the integration of WBV alongside conventional treatments to be a viable and beneficial approach to therapy. In-depth and enhanced research is necessary to examine the neurophysiological impacts of WBV that could aid in improving IR associated with PCOS.

Conclusions

This study reveals that WBV has favorable effects on IR and hormonal parameters in females with PCOS.

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Conflicts of interest

The authors declare no conflict of interest.

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