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Improvement in Lipid Profile and Sex Hormones with Oleoylethanolamide Supplement in Women with Polycystic Ovary Syndrome: A Clinical Trial

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ABSTRACT

Background: Oleoylethanolamide (OEA) has shown anti-inflammatory and antioxidant effects in previous studies. Considering that disruption of the lipid profile and sex hormones is a prevalent symptom in polycystic ovary syndrome (PCOS), this study aimed to evaluate the effects of OEA supplementation in women with PCOS. **Method**: In a randomized placebo-controlled trial, 90 women diagnosed with PCOS were divided into two groups: one receiving 125 mg/day OEA (OG, n=45) and the other receiving a placebo (PG, n=45), for 8 weeks. Dietary intake and physical activity were assessed using validated questionnaires, and anthropometric indices were measured according to standard procedures. Moreover, serum lipid profile components and sex hormones were measured using ELISA kits. Biochemical parameters were assessed at baseline and after the intervention. Statistical analyses were performed using SPSS software. **Results:** At the end of the study, the OG showed a significant decrease in the levels of total cholesterol, triglycerides, low-density lipoprotein, prolactin, and total testosterone compared to both PG and baseline (P<0.005). However, the levels of HDL, FSH, and LH did not show any significant change (P>0.005). **Conclusion:** With OEA antioxidant and anti-inflammatory properties, this fatty acid supplement can help reduce symptoms by improving dyslipidemia and sex hormone levels, especially testosterone.

Introduction

Polycystic ovary syndrome (PCOS) is one of the most common health disorders among young women and is typically characterized by hormonal imbalance, menstrual irregularities, and metabolic disturbances. The prevalence of this syndrome is reported to range from 4% to 10% (Singh *et al.*, 2023). Although the exact etiology of PCOS remains unclear, several factors - including environmental influences, insulin resistance (IR), inflammation, reduced antioxidant capacity, obesity, and dietary factors - are believed to contribute to its development (Sadeghi and Adeli, 2022). Hyperandrogenism refers to elevated levels of male hormones, primarily testosterone, in females. Increased androgen levels can lead to the development of masculine traits and irregular menstrual cycles (Sharma and Welt, 2021).

Previous studies have reported dyslipidemia in women with PCOS. These alterations in lipid levels are thought to originate from hyperinsulinemia, which suppresses the production of sex hormone-binding globulin (SHBG). SHBG plays a crucial

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role in maintaining serum androgen levels within the normal range. Hyperandrogenemia is believed to contribute to the abnormal lipid profiles observed in women with PCOS (Liu *et al.*, 2019).

In addition to elevated testosterone levels, alterations in prolactin (PRL) levels have also been reported in women with PCOS (Yang *et al.*, 2020). However, studies investigating PRL levels in patients with PCOS have yielded conflicting results, with some reporting lower-than-normal levels and others reporting elevated levels. Dysregulation of PRL may also be linked to carbohydrate metabolism. Both elevated and reduced PRL levels may serve as indicators of IR and type 2 diabetes, respectively (Davoudi *et al.*, 2021, Yang *et al.*, 2020).

In PCOS, luteinizing hormone (LH) levels are often higher than follicle-stimulating hormone (FSH) levels. This hormonal imbalance may result from dysfunction of the hypothalamic-pituitary-gonadal (HPG) axis (Zheng *et al.*, 2024). Additionally, impaired ovarian negative feedback on LH secretion may lead to persistently elevated LH levels. Elevated LH levels can disrupt the ovulatory process (Saadia, 2020).

The interaction between the HPG axis, ovaries, and uterus with peroxisome proliferator-activated receptors (PPARs) plays an important role in energy metabolism and ovarian function. Studies in PPAR-α knockout mice have shown that PPAR-α influences pituitary activity during fasting. PPAR-α and PPAR-γ are believed to play crucial roles in follicular rupture during ovulation and corpus luteum formation (Vitti and Di Emidio, 2016).

Oleoylethanolamide (OEA) is an endogenous lipid mediator derived from oleic acid, which is abundant in olives and olive-derived products (Bowen *et al.*, 2017). The OEA regulates energy metabolism by binding to receptors such as PPAR-α and G-protein-coupled receptor 119 (GPR119), both of which are involved in lipid metabolism and inflammatory responses (Comerota *et al.*, 2023, Payahoo and Khajebishak, 2018). In a study conducted by Payahoo *et al.*, 60 obese but otherwise healthy individuals received 125 mg OEA capsules twice daily for eight weeks. The intervention group demonstrated a significant reduction in serum IL-6 and TNF-α concentrations (Payahoo and Khajebishak, 2018). In a study conducted by Tutunchi *et al.*, 76 patients with NAFLD and obesity received a weight-loss diet along with 250 mg OEA or placebo. The OEA group showed significantly lower LDL-C/HDL-C, TG/HDL-C, and non-HDL-C/HDL-C ratios compared to the placebo group (Tutunchi *et al.*, 2020).

Considering the findings of previous studies on the effects of OEA, the present study aimed to investigate, for the first time, the effects of OEA supplementation on lipid profile and sex hormones in women with PCOS.

Materials and Methods

Participants

Only patients who met the Rotterdam criteria (Christ and Cedars, 2023) were included in this study. The presence of two or three of the following conditions considered as Rotterdam criteria: irregular ovulation, excessive androgen levels, and/or polycystic ovarian morphology.

To qualify patients, they had to present with at least two of the following three symptoms: hyperandrogenism, oligomenorrhea, and the presence of cysts in the ovary at an ultrasound scan. Cases were also selected based on being between the ages of 18 and 45 and having a body mass index (BMI) in the range of 25 to 30. Patients with the following conditions were excluded from the study: pregnancy, breastfeeding, menopause, infectious or inflammatory disease, Cushing's syndrome, adrenal gland tumor, hypothyroidism, increased blood PRL, acromegaly, diabetes, cancer, hormone therapy in the last 3 months, use of antioxidant supplements in the past 3 months, drug use over the past three months, including contraceptives, glucocorticoids, cholesterol-lowering drugs, and weight-reducing drugs. The patients were referred to the Infertility and Gynecology clinic at Qazvin University of Medical Sciences and were under the care of a specialist physician.

Study design

This study was a randomized, double-blind, placebo-controlled clinical trial that considered the effects of taking 125 mg/day of OEA for eight

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weeks on lipid profile and sex hormones. BMI was calculated by dividing a person's weight in kilograms by the square of their height in meters (Weir and Jan, 2023). The three-day dietary recall and international physical activity questionnaire (IPAQ) (Maddison *et al.*, 2007) were assessed to compare the food intake and physical activity of participants. For each person, weight was calculated by using a Seca scale, and height using a tape measure in a standing and straight position. By using random numbers, participants were randomly allocated to two groups: OEA group (OG, n=45) and placebo group (PG, n=45). Each participant in the OG was given a daily OEA tablet (125mg), while the PG received a tablet with same amounts but containing wheat flour. The consumption of supplements was monitored weekly through phone follow-ups. The supplement tablets were indistinguishable from the placebo tablets in terms of color, shape, and size. The patient, researcher, and specialist physician were unaware who received the supplement and the placebo. The tablets for two distinct groups were prepared by an external party and placed in identical packaging, making it impossible for the administrator to distinguish their contents. The OEA supplement was purchased from Supplement Fact, while the placebo was manufactured by the School of Pharmacy at Tabriz University of Medical Sciences. Patients were instructed to maintain their regular diet and physical activity routines throughout the study. The patients were monitored weekly via phone calls. Any changes in their condition were noted during these calls. The effective dosage of the OEA and duration of the study were determined based on the research of Pouryousefi (Pouryousefi *et al.*, 2022). To analyze the food intake data, the authors used the Nutritionist IV program modified for Iranian food composition (Ghadimi *et al.*, 2021).

Sample size

In the study of Payahoo *et al.*, TNF-α factor was associated with a significant decrease in the group receiving OEA supplement; therefore, the sample size was estimated based on this factor in the following formula (Payahoo *et al.*, 2018). The mean and standard deviation of the TNF-α before and after the supplementation was 44.19±6.30 and 20.40±4.20, so it was calculated as 40 people for each group, and 45 people were considered in each group due to the possibility of dropping out.

$$N= [(Z_{1-\alpha/2} + Z_{1-\beta})^2 (SD_1^2+SD_2^2)] /\Delta^2$$

Laboratory methods

After a 12-hour overnight fast, 10 ml of blood was collected from each person. The blood samples were kept in the freezer until all patients had their samples collected. Vacuum collection tubes containing EDTA were used to collect the blood samples. The serums were then separated by high-speed centrifugation and immediately frozen at -70 °C. The concentration of total cholesterol, TG, HDL, LDL, total testosterone, PRL, LH, and FSH was measured using an ELISA kit.

Randomization procedure

Block randomization using computer-generated random allocation sequences: allocation concealment was performed using sequentially numbered, opaque, sealed envelopes. The randomization sequence was generated by an independent statistician not involved in recruitment or analysis.

Blinding procedure

Double blinding (participants, investigators): supplement and placebo were identical in appearance, packaging, labeling, weight, smell, and taste. Code disclosure occurred only after statistical analysis was completed.

Dietary assessment

Three-day dietary recall analyzed using Nutritionist IV software to control for potential confounding effects of dietary variations on metabolic and hormonal outcome. The data of this questionnaire was assessed twice, before and after the intervention, to compare the differences.

Physical activity

The IPAQ (International Physical Activity Questionnaire) was used to assay the level of physical activity.

Anthropometric measures

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The seca calibrated digital scale for weight measurement (precision 0.1 kg). Height was measured with wall-mounted stadiometer (precision 0.1 cm). Then, measurements were taken twice and were averaged.

The inclusion criteria regarding age and BMI were applied to reduce clinical heterogeneity and improve internal validity. Age and adiposity are major determinants of metabolic and hormonal status in women with PCOS. Restricting these variables helped reduce variability and increased the ability to detect the true effect of OEA supplementation.

Ethical considerations

The Ethics Committee of Qazvin University of Medical Sciences in Iran approved the study protocol, with the ethics code IR.QUMS.REC.1400.370. The study was registered with the Iranian Registry of Clinical Trials (http://www.irct.ir, Registration Number: IRCT20141025019669N20). All female patients with PCOS who participated in the study provided their consent by signing the consent forms before the intervention. The study followed the standards of the Declaration of Helsinki and current ethical guidelines. It was conducted at the Infertility and Gynecology Clinic of Qazvin University of Medical Sciences.

Data analysis

In this study, statistical analyses were performed using SPSS version 20. All data were presented as mean with standard deviation (mean±SD), and the normality of data distribution was assessed using the Kolmogorov-Smirnov test. The paired *t-test* was used to compare mean variables within each group, and the independent sample *t-test* was used to compare variables between two groups. A p-value less than 0.05 was considered statistically significant in this research. The study was designed and reported in accordance with CONSORT guidelines to ensure transparency, methodological rigor, and reproducibility.

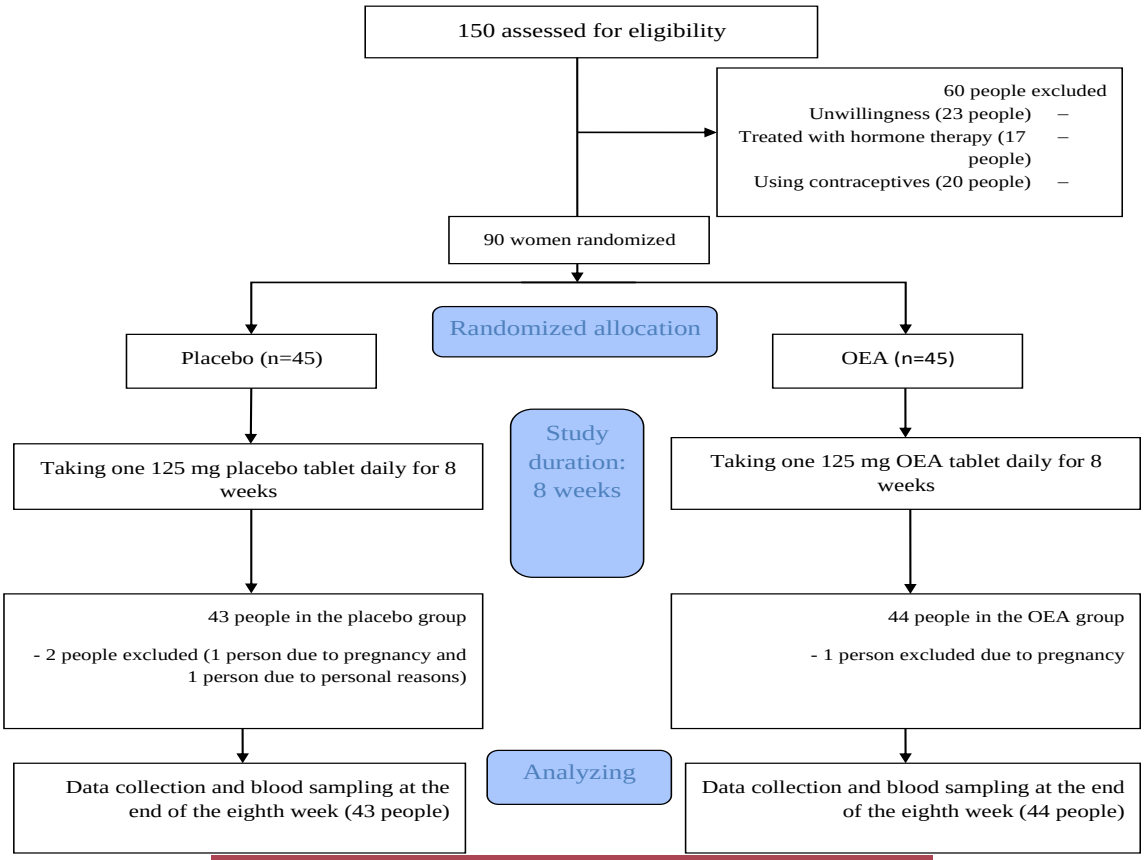

Figure 1. The design of the double-blind randomized trial.

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Results

Of the 90 women participating in this study, two in the OG were excluded due to pregnancy and one in the PG due to personal reasons (**Figure 1**). The participation rate in this study was 96.66%.

Table 1 represents the demographic information of each group with the mean±SD. There were no significant changes observed between the two groups and also from the baseline (P>0.05). The three-day dietary recall for dietary food intake did not show any significant difference between the two groups. The amounts of potent antioxidant foods such as vitamin E, C, and selenium were assessed to avoid any interference with the intervention (**Table 2**).

In the OG, significant improvements in lipid profile were observed, with a marked reduction in total cholesterol, TG, and LDL compared to the placebo group and also at the baseline (P<0.05). Although there was no statistically significant change observed in HDL, the OG showed a slight increase in its levels (P>0.05). **Table 3** provides information regarding lipid profiles. Furthermore, the study analyzed sex hormones such as PRL, total testosterone, LH, and FSH in both groups, and the results were presented in **Table 4**. The OG showed a significant reduction in PRL and total testosterone levels (P<0.05) in comparison to the PG and baseline. Although there were no significant changes in LH and FSH levels in the OG, there was a slight decrease in LH and a slight increase in FSH compared to the beginning of the study and the PG (P>0.05).

Discussion

The results showed, in comparison to the PG and baseline, the OEA supplement could significantly improve Hyperandrogenism and dyslipidemia. This includes a significant reduction in PRL, testosterone, cholesterol, TG, and LDL independent of food intake and weight loss. While statistical significance was not quantified for LH, FSH, and HDL, FSH and HDL increase and LH decrease were insignificant in the OG.

Several studies have highlighted the anti-inflammatory and antioxidant properties of OEA in metabolic diseases. Sun *et al.* demonstrated that OEA could boost the expression of I_kB, an inhibitory protein of NF-kB (Sun *et al.*, 2007), which was an anti-inflammatory property. Anti-inflammatory properties of OEA proved in the study of Tutunchi *et al.'s* also supports this finding, as it showed that OEA reduced the levels of CRP, IL-6, TNF-a, and IL-10 (Tutunchi *et al.*, 2023). Payahoo *et al.* also resulted after 8 weeks of supplementation with 250 g/day OEA, IL-6 and TNF-α reduced potentially (Payahoo and Khajebishak, 2018). Women with PCOS often experience dyslipidemia due to hyperandrogenism, which can also lead to chronic inflammation (Liu *et al.*, 2019).

Table 1. The comparison of baseline characteristics of the participants.

Variable	Placebo group (n=43)	Oleoylethanolamide group (n=44)	P-value[a]
Age (y)	29.13±5.24[c]	27.36±4.80	0.253
Height(cm)	159.26±5.71	161.79±4.21	0.612
Weight (kg)			
Before	71.19±8.23	73.50±6.39	0.409
After	70.34±7.68	72.00±8.14	0.430
P-value[b]	0.481	0.425	
BMI (kg/m²)			
Before	28.06±0.25	28.00±0.36	0.501
After	27.81±0.34	27.51±0.45	0.214
P-value	0.329	0.302	
Physical activity			
Before	34.19±4.33	35.90 ±5.81	0.203
After	34.67±5.74	36.10±6.12	0.265
P-value	0.32	0.401	

*[a]: Independent samples t-test; [b]: Paired samples t-test; [c]: Mean± SD; **BMI**: Body mass index.*

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Table 2. The comparison of the dietary intake of the participants in placebo and OEA group .

Variable	Placebo group (n=43)	Oleoylethanolamide group (n=44)	P-value[a]
Energy(kcal)			
Before	2179.36±303.22[c]	2257.11±298.43	0.619
After	2101.03±319.09	2209.19±308.11	0.683
P-value[b]	0.656	0.693	
Protein(g/d)			
Before	88.50±21.19	91.34±23.50	0.203
After	88.03±21.5	91.11±24.50	0.210
P-value	0.35	0.394	
Carbohydrate (g/d)			
Before	303.00 ±49.5	308.12±55.50	0.325
After	302.29±47.18	305.77±53.09	0.380
P-value	0.45	0.401	
Fat (g/d)			
Before	69.02±4.50	68.11±5.13	0.367
After	66.09±6.80	69.39±6.07	0.291
P-value	0.265	0.31	
Saturated fatty acids(g/d)			
Before	27.50±4.21	26.15±5.70	0.230
After	25.03±4.06	26.11±5.10	0.207
P-value	0.19	0.311	
Monounsaturated fatty acid (g/d)			
Before	20.08±3.19	22.13±3.19	0.807
After	20.10±4.19	22.17±3.55	0.590
P-value	0.298	0.74	
Polyunsaturated fatty acid (g/d)			
Before	19.63±4.35	20.03±4.41	0.213
After	19.18±3.13	20.16±4.60	0.204
P-value	0.269	0.293	
Fiber(g/d)			
Before	9.16±2.90	10.04±3.33	0.136
After	9.87±2.12	10.22±3.08	0.140
P-value	0.157	0.148	
Vitamin C (mg/d)			
Before	69.21±17.50	70.77±14.32	0.415
After	68.65±19.2	70.54±12.77	0.302
P-value	0.288	0.311	
Vitamin E (IU/d)			
Before	11.31±2.02	11.59±3.00	0.289
After	11.06±2.31	11.24±2.66	0.231
P-value	0.24	0.267	
Selenium (µg/d)			
Before	116.14±29.50	117.02±35.70	0.354
After	116.02±25.00	117.60±34.61	0.329
P-value	0.39	0.402	

[a]: Independent samples t-test; [b]: Paired samples t-test; [c]: Mean± SD.

In the study by Fan *et al*., supplementation with 5 mg/kg/day of OEA administered by intraperitoneal injection for 14–17 weeks prevented the formation of atherosclerotic plaques in the vascular system by inhibiting the modification of LDL (Fan *et al.*, 2014). Also, in the study of Sabahi *et al*. HDL level increased significantly with the dose of 300 mg/day OEA for three days (Sabahi *et al.*, 2022). This may be due to the higher dose of OEA or the absence of hormonal issues. Tutunchi *et al*. concluded that 250 mg OEA for 12 weeks significantly decreased

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LDL-C/HDL-C and TG/HDL-C ratio (Tutunchi *et al.*, 2020). In line with the Tutunchi's study, in this study lipid profile in the OEA-receiving group improved. LDL, TG, and total cholesterol significantly decreased, but HDL insignificant increase in the OEA group.

Table 3. Changes in baseline to endpoint measures for lipid profile in two groups.

Variable	Placebo group (n=43)	Oleoylethanolamide group(n=44)	P-value[a]
Total cholesterol (mg/dl)			
Before	189.00±61.52[c]	192.29±59.19	0.605
After	191.71±55.14	175.88±56.54	0.022
P-value[b]	0.666	0.0214	
Triglyceride (mg/dl)	1		
Before	61.72±25.17	162.72±19.34	0.527
After	160.47±26.81	142.21±11.13	0.031
P-value	0.540	0.036	
High density lipoprotein (mg/dl)			
Before	34.66±9.49	35.40±9.18	0.243
After	33.09±11.11	36.65±10.19	0.092
P-value	0.290	0.110	
Low density lipoprotein (mg/dl)			
Before	122.34±46.70	124.89±46.01	0.411
After	124.52±38.83	109.23±43.85	0.039
P-value	0.439	0.033	

[a]: Independent samples t-test; [b]: Paired samples t-test; [c]: Mean± SD.

Other anti-inflammatory supplements have been shown to improve the lipid profile in PCOS patients. For instance, 200 µg chromium picolinate supplementation could decrease serum TG, very low-density lipoprotein-cholesterol (VLDL), and cholesterol concentrations in PCOS women (Jamilian and Asemi, 2015). Khani *et al.* compared omega-3 supplement (2 g/day) with olive oil capsules for 6 months in PCOS sufferers. The results indicated significantly increased levels of HDL while decreased levels of LDL, TG, and cholesterol compared to the control group. Also, the frequency of periods in the omega-3 group was significantly higher than that of the control group (Khani *et al.*, 2017). Additionally, taking a 50000 IU vitamin D supplement for 8 weeks resulted in a decrease in TG levels, but did not affect LDL, HDL, and cholesterol levels. Vitamin D supplementation also did not cause significant changes in sex hormones, including testosterone, LH, and FSH (Irani *et al.*, 2017).

The female reproductive system is associated with neuroendocrine pathways, including the HPG axis (Goldsammler *et al.*, 2018), which is responsible for follicular growth (Arao *et al.*, 2019). In cases of PCOS, there is a dysregulation in the HPG axis, which can be linked to inflammation (Zheng *et al.*, 2024). Under the effect of high levels of androgens, the androgen receptors that exist on HPG axis cells can suppress the secretion of LH and FSH (Sharma and Welt, 2021). On the other hand, some disorders in the HPG axis such as the lack of negative feedback regulation for LH can cause its level to increase abnormally, leading to a decrease in FSH level. This results in an increased ratio of LH to FSH, 2 to 3 times higher in women with PCOS (Saadia, 2020). This study was the first to investigate the effects of OEA on sex hormones. In this study, the authors found that OEA did not have any significant effect on LH and FSH. The findings showed a significant decrease in testosterone levels, which is the main hormone responsible for hyperandrogenism and external manifestations such as hirsutism and acne (Sharma and Welt, 2021). Some supplements that have antioxidant and anti-inflammatory properties may have an impact on testosterone levels. For instance, a study has found that taking 1 g of omega-3 fatty acids along with 400 IU of vitamin E daily for a period of 12 weeks resulted in a significant decrease in

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both total and free testosterone levels compared to the placebo group (Ebrahimi *et al.*, 2017). Similarly, another study conducted by Amr *et al*. revealed that supplementation with 1 g chromium for 6 months led to a significant reduction in testosterone levels (Amr and Abdel-Rahim, 2015). This may suggest that antioxidant or anti-inflammatory interventions are effective in regulating testosterone levels. The PRL is an essential hormone that plays a crucial role in regulating the levels of testosterone in the body (Sharma and Welt, 2021). High levels of PRL can stimulate the production of testosterone (Yang *et al.*, 2020). On the other hand, a study by Yang *et al.* found an inverse correlation between the concentrations of serum PRL, LH, and LH/FSH ratios (Yang *et al.*, 2020), indicating that PRL levels in PCOS can vary.

Table 4. Changes in baseline to endpoint measures for sex hormones levels in two groups.

Variable	Placebo group (n=43)	Oleoylethanolamide group (n=44)	P-value[a]
FSH (ng/ml)			
Before	6.59±1.85[c]	6.65±1.90	0.129
After	6.35±1.48	6.72±1.85	0.103
P-value[b]	0.110	0.141	
LH (ng/ml)			
Before	10.26±1.59	10.58±2.69	0.360
After	10.37±2.50	9.49±2.75	0.073
P-value	0.419	0.069	
Total testosterone (ng/ml)			
Before	0.73±0.02	0.69±0.01	0.101
After	0.7±0.03	0.33±0.02	0.035
P-value	0.110	0.036	
Prolactin (ng/ml)			
Before	20.36±5.03	20.09±4.87	0.612
After	19.91±4.50	11.06±3.64	0.038
P-value	0.594	0.034	

[a]: Independent samples t-test; [b]: Paired samples t-test; [c]: Mean± SD; ***FSH****: Follicle-stimulating hormone;* ***LH****: Luteinizing hormone.*

The most important novel aspect of this study is the simultaneous improvement of dyslipidemia and hyperandrogenism. While previous investigations have reported metabolic benefits of OEA in obesity and non-alcoholic fatty liver disease, no prior randomized trial has evaluated its effects on reproductive hormones in PCOS. The observed reduction in total testosterone is particularly clinically relevant, as hyperandrogenism represents a central pathophysiological feature of PCOS and is directly responsible for symptoms such as hirsutism, acne, and menstrual irregularity.

This study did not compare PRL levels in PCOS to normal women. However, OEA significantly reduced PRL levels compared to placebo. While we did not assess molecular pathways, but previous literature has suggested that PPAR-α is crucial for ovulation and luteum formation. OEA, as a PPAR-α antagonist, can affect the reproductive system (Vitti and Di Emidio, 2016).

Given the chronic nature of PCOS and the limitations of long-term pharmacologic therapy, identifying safe adjunctive nutritional strategies is clinically valuable. The absence of significant weight loss during the intervention indicates that the observed biochemical improvements were not secondary to body mass reduction, strengthening the hypothesis of a direct metabolic-hormonal mechanism. If confirmed in larger and longer-term trials, OEA supplementation may represent a promising adjunct strategy for improving cardiometabolic and androgen-related abnormalities in PCOS.

This study had both strengths and weaknesses. One of the strengths was that the authors examined this issue for the first time, which was important considering the potential effects of OEA and PCOS. Additionally, the cooperation of the participants who did not withdraw from the study helped to maintain

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the study population and strengthened the results. The use of a double-blind method and randomization also helped to validate the study. However, one of the weak points of the study was the lack of evaluation of other characteristics resulting from the effect of OEA. For instance, the effect of OEA on the clinical characteristics of hyperandrogenism and the regularity of menstrual cycles were not investigated. Moreover, the ultrasound evaluation was limited to checking the changes before and after the intervention of OEA and placebo. Therefore, it is suggested to investigate the use of polycystic ovary morphology ultrasound in future studies. Among the limitations of the study, we can mention the limitations of previous studies in the field of PCOS and hormonal diseases of women with OEA. These limitations restricted the comparison and evaluation of the results. Additionally, due to the time limit for sampling and the need to prevent prolongation of the study, it was not possible to evaluate more factors. This study showed that eight weeks of intervention with an OEA supplement could have a significant impact on the biochemical factors of women with the condition. Dyslipidemia in PCOS, which is a potential risk factor for heart disease, showed improvement after the OEA intervention. More importantly, the increased levels of testosterone, which is responsible for many symptoms of PCOS, were significantly reduced with the OEA supplement.

Conclusion

The findings suggest that OEA may exert beneficial metabolic and endocrine effects in PCOS, potentially through lipid-modulating mechanisms. Given the central role of dyslipidemia and hyperandrogenism in the pathophysiology of PCOS, OEA supplementation may represent a promising adjunctive strategy for improving cardiometabolic and hormonal abnormalities in this population.

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Authors' contributions

Taghizadeh Shivyari F, Pakniat H, Rashidi Nooshabadi M and Khadem Haghighian H designed the research. Taghizadeh F, Rashidi Nooshabadi M, Khadem Haghighian H and Rostami S conducted the research. Formal analysis and investigation were done by Taghizadeh F, Rashidi Nooshabadi M, and Khadem Haghighian H; Writing - original draft preparation was carried out by Taghizadeh F and Khadem Haghighian H. Writing - review and editing was done by Khadem Haghighian H; Funding acquisition was by Khadem Haghighian H; and resources were collected by Rashidi Nooshabadi M and Taghizadeh F; Supervision: Khadem Haghighian H. All authors have read and approved the final manuscript.

Conflict of interest

The authors declared no conflict of interest related to this study.

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