Evaluation of the efficacy of different sources of omega-3 fatty acids in polycystic ovarian syndrome (PCOS) induced rats

Fiza Komal[1], Mahr-Un-Nisa[1]*, Muhammad Kamran Khan[1], Usman Ali Ashfaq[2], Faiza Manzoor[1], Amna Masroor[1], Rai Muhammad Amir[3], Noor-Ul-Huda[4], Rukhsana Kausar[5] and Muhammad Nadeem[6]

[1]Department of Food Science, Nutrition and Home Economics, Government College University, Faisalabad, Punjab, Pakistan
[2]Bioinformatics and Biotechnology, Government College University, Faisalabad, Punjab, Pakistan
[3]Institute of Food and Nutritional Sciences, PMAS-Arid Agriculture University, Rawalpindi, Pakistan
[4]Institute of Home Sciences, University of Agriculture Faisalabad, Toba Tek Singh Campus, Punjab, Pakistan
[5]Department of Environmental Sciences, International Islamic University, Islamabad, Pakistan
[6]Department of Environmental Sciences, COMSATS University Islamabad, Vehari Campus, Pakistan

Abstract: The study was planned to check the beneficial effects of various sources of omega-3 fatty acids (synthetic, flaxseed oil, fish oil) on 45 Wistar female rats. The rats were divided into five groups and assigned to different diets i.e. NC (Negative control), PC (Positive control), SO (Synthetic omega-3 250mg/kg/orally/daily), FO (flaxseed oil 250mg/kg/orally/daily) and F (fish oil 250mg/kg/orally/diet). Animals fed on different diets were induced PCOS by an intramuscular (IM) injection of estradiol-valerate (4mg/rat/IM) except NC group. Results of the lipid profile indicated that F showed highest increase in HDL level (35.67±1.45), while cholesterol, LDL, triglycerides, blood glucose and body weight were reduced in all three treatment groups. In case of a hormonal profile, testosterone, luteinizing hormone (LH) and insulin levels showed a significant reduction after treatments. It can be concluded form the study that different sources of omega-3 fatty acids can be a new approach to treat the symptoms of PCOS.

Keywords: Syndrome, infertility, dietary, omega-3, estradiol valerate.

INTRODUCTION

Polycystic ovary syndrome (PCOS) is the most known endocrine disorder in women who are at reproductive age, developing as a set of symptoms and diseases with moderate to severe protests in the functioning of hormonal, metabolic and reproductive systems (Trikudanathan, 2015). This is caused by polycystic ovaries, irregular menstruation, hyperandrogenism, insulin resistance and obesity experienced in 5 to 20 % of women depending on the diagnostic criteria (Pourghassem *et al.,* 2015).

Definitive origins of PCOS are unknown and may be caused by a mixture of factors such as increased androgenicity, genetic factors, environmental factors and epigenetic factors (Nardo *et al*., 2008). Many females with PCOS have developed insulin resistance, apart from weight. For this purpose, moderation in daily life that leads to the development of insulin sensitivity should be confirmed as the first treatment in this syndrome, especially in those situations where there is difficulty with excess weight and obesity (Norman *et al*., 2002).

Several natural treatments for PCOS have been recognized in various herbal treatments but the most common treatment is the use of omega-3 fatty acids in approaching PCOS management. It was noted that polyunsaturated fatty acids (PUFAs) may be associated with improved metabolic and endocrine properties in PCOS patients (Kasim-Karakas *et al*., 2004). Various studies have noted that dietary PUFAs from fish oil may also have beneficial effects on lipid profile and glycemic control as they have increased antiatherogenicity and anti-inflammatory properties (Oh, 2005).

Numerous diseases associated with PCOS enhanced omega-3 PUFAs consumption. Clinical and experimental studies have confirmed that omega-3 PUFAs reduces hyperinsulinemia, obesity and inflammation, increases insulin sensitivity and decreases triglyceride (Cussons *et al*., 2009). Therefore, subjects with PCOS are regularly recommended to improve omega-3 PUFAs.

In infertile women, omega-3 PUFAs have been assumed to contribute to the management of infertility, as eicosapentaenoic acid (EPA) plasma levels and erythrocyte decosahexaenoic acid (DHA) levels are reduced compared to controls (Mehendale, 2009). The addition of omega-3 fatty acids refers to a reduced risk of hypertension induced by pregnancy, premature birth and fetal growth restriction. Omega-3 fatty acids make it easier for the body to increase blood flow to the uterus, regulate the hormone, reduce susceptibility to hormone prolactin, which can suppress ovulation, increase the mucus of the cervical protein that is needed to help sperm contact the egg. It helps the cycle to become normalized (Saldeen and Saldeen, 2004).

**Corresponding author:* e-mail: linknisa@gcuf.edu.pk

The effects of omega-3 fatty acids were observed in women with PCOS by controlling other factors responsible for causing PCOS. A recent research plan has shown that various omega-3 fatty acid sources have a beneficial role in weight management, reducing high cholesterol levels and controlling blood glucose that induces signs to stimulate PCOS. The purpose of this study was to check the individual effects by which different omega-3 fatty acid sources can improve lipid and hormonal profile, body weight and glucose levels in PCOS-induced rat models.

MATERIALS AND METHODS

Research area

The study was conducted at the Department of Food Science, Nutrition and Home Economics and Department of Physiology, Government College University, Faisalabad and Department of Animal Sciences, University of Agriculture Faisalabad.

Product used

The dietary sources of omega-3 fatty acids (flaxseed oil and fish oil) have been bought from the famed food market of Faisalabad. Its synthetic source was purchased from well reputed pharmacy.

Procuring rats and their management

Forty-five Wistar Albino female rats (forty-five days old), each weighing 130±10 grams, which have 2 consecutive estrus cycles had been bought from National Institute of Health, Islamabad. They were kept at 25 ± 1°C and relative humidity of 45 to 55% under twelve hours light: twelve hours dark cycle. All animals were treated according to Principles of Laboratory Animal Care. The experimental procedure was accepted by the Animal Ethical Committee. Animals were fed regular diet and water was offered *ad libitum*. Diets were *isocaloric* and *isonitrogenous.*

Experimental protocol

The rats were divided into five groups (9 rats per group) named according to diets viz.

Group 1: Normal control rats (NC)
Group 2: Rats injected with 4mg/rat/Intra muscular of estradiol-valerate (PC)
Group 3: PCOS induced rats received synthetic omega-3 (250mg/kg/orally/daily) (SO 250mg/kg/orally/daily)
Group 4: PCOS induced rats received flaxseed oil (250mg/kg/orally/daily) (FO 250mg/kg/orally/daily)
Group 5: PCOS induced rats received fish oil (250mg/kg/orally/daily) (F 250mg/kg/orally/daily)

NC and PC groups were fed basal diet. All animals except negative control were induced PCOS by an intramuscular injection of estradiol-valerate (4mg/rat/IM). In this *in vivo* assay, rats were divided in to a fully Completely Randomized Design (CRD). Each treatment was repeated 3 times to make 15 experimental units, each of which has three white rats including 45 rats as a whole. At the end of the trail, rats were killed and blood samples were collected to evaluate the lipid and hormonal profile.

Data collection

Data on some parameters like body weight and blood glucose was collected weekly during this experiment.

Determination of Fatty Acid (FA) Composition

Fatty acid composition was determined by gas chromatography (Ali and Muhammad, 2013).

Biochemical analysis

Lipid Profile was checked by microplate reader URIT 660. Cholesterol was determined with kit method by using Biosystem cholesterol kit REF. 11505 (Barcelona, Spain). Triglyceride was estimated by Triglycerides liquiform mono reagent kit (Paris, France). HDL and LDL were determined by Wiener kit having REF. 1220229 and REF 1220114 respectively (Rosario, Argentina). Blood glucose was determined by glucose glucometer Accuchek Active®. Body weight was measured by Weighting Balance. Testosterone, Follicle stimulating hormone (FSH), Luteinizing hormone (LH), Progesterone, Prolactin and Estrogen were estimated via Enzyme Linked Immunosorbent Assay (ELIZA) by using kits method (Biocheck, Inc. Foster City, CA 94404, U.S.A). Insulin was also checked by ELIZA by using kit (Monobind Inc. Lake Forest CA 92630 U.S.A).

STATISTICAL ANALYSIS

All the data collected were statistically measured for mean and standard error. Statistical analysis was carried out using SPSS (Version 17). Comparison of means between groups was observed via Duncan Multiple Range Test (Steel *et al*., 1997).

RESULTS

Effect on Lipid Profile

The statistical results regarding cholesterol, triglycerides, HDL and LDL levels of rats fed SO, FO and F diets have been shown in table 1 and fig. 1. Results indicated that rats fed SO, FO and F diets exhibited significant decrease ($P<0.05$) in serum cholesterol, triglycerides and LDL in PCOS induced rats as compared to PC rats. The level of HDL was reduced in all groups induced by PCOS as compared to NC. The HDL level significantly increased in SO, FO and F diets after treatment, but the best result was the F (35.67 ± 1.45) group which showed a significant improvement in HDL levels compared to PC. Mostly, the results between F and SO were non-

significant. SO and FO were also non-significant to each other.

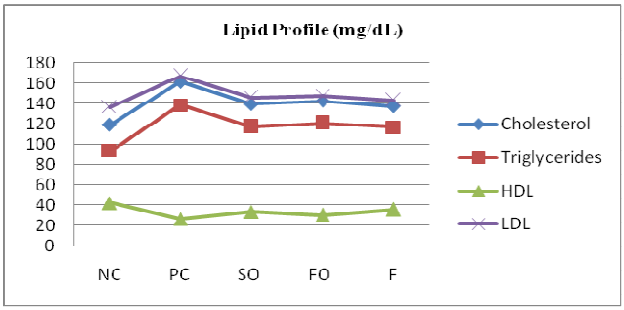

Fig. 1: Effect of Different Sources of Omega-3 Fatty Acids on Lipid Profile in PCOS induced rats

Hormonal Profile

The results of hormonal profile showed that testosterone, LH, prolactin and insulin levels increased in all PCOS groups shown in table 2 and fig. 2. After the introduction of the treatments, the levels of testosterone, LH and insulin were significantly reduced in SO, FO and F groups. However, all treatments were not significant to each other and were significant from the PC. In case of prolactin, all treatments increased the prolactin level in a numerical way compared to the PC, but their overall effect was not significant. In all PCOS induced groups FSH, progesterone and estrogen levels were reduced compared to NC. The addition of SO, FO and F diets showed no significant effect on FSH, progesterone and estrogen. No significant differentiation between PC and treatment groups was found.

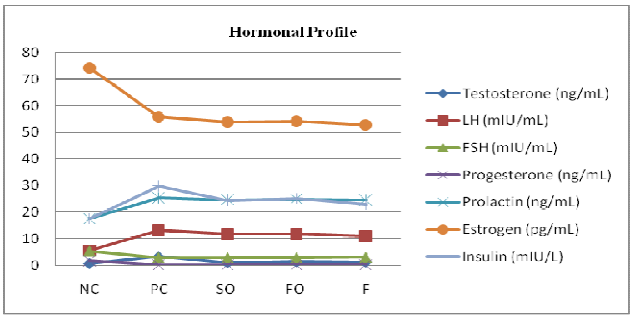

Fig. 2: Effect of Different Sources of Omega-3 Fatty Acids on Hormonal Profile in PCOS induced rats

Effect on Blood Glucose

The results showed that after the induction of PCOS, blood glucose levels increased significantly as compared to NC diet depicted in table 3 and fig. 3. The addition of SO, FO and F diets did not explain any significant effect on blood glucose levels till the last of 4th week, although blood glucose levels were abruptly reduced with PC over time. After the 4th week of experiments, dietary treatments were significantly reduced blood glucose levels rather than PC. In the next three weeks (5th, 6th and 7th) blood glucose reduction levels were non-significant between SO, FO and F groups but all were significant from PC group. But this effect was not equal to negative control. In last three weeks of trial (8th, 9th and 10th) F showed better results as 142.63±1.17, 140.83±0.44 and 141.00±0.58 respectively. The effect of F was statistically significant as compare to PC. F and SO groups were non-significant to each other. Same trend was seen between SO and FO groups.

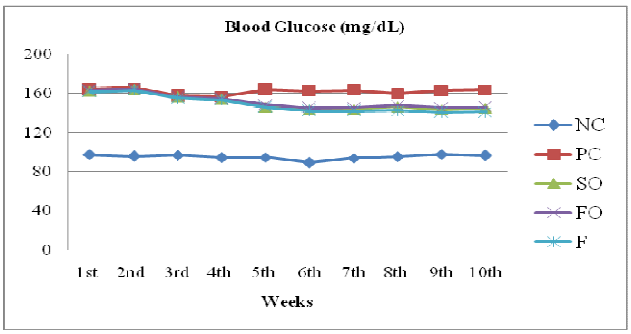

Fig. 3: Effect of Different Sources of Omega-3 Fatty Acids on Weekly Blood Glucose in PCOS induced rats

Effect on Body Weight

The body weight of PCOS induced rats did not show any significant effect after adding the SO, FO and F diets till the end of fifth week shown in table 4 and fig. 4. After the fifth week of experiments, dietary treatments significantly reduced the body weight of all rats fed SO, FO and F diets. In the next three weeks (6th, 7th and 8th) weight loss was not significant between SO, FO and F groups but all were significant from PC group. In the 6th week the best result was visible in SO (153.11 ± 0.67) group. In the 7th week, SO and F showed the same weight reduction trend of 155.23 ± 0.82 and 155.23 ± 0.75. In the 8th week, the best result was seen in F (159.59 ± 1.42) group. In the last two weeks (9th and 10th) the F diet effect was statistically significant compared to PC and FO. Although the effect of SO and FO was also significant as comparison with the PC. F and SO were non-significant. The same trend was observed between SO and FO. In 9th and 10th week FO shows better results of 163.06 ± 0.63 and 167.92 ± 1.06, respectively.

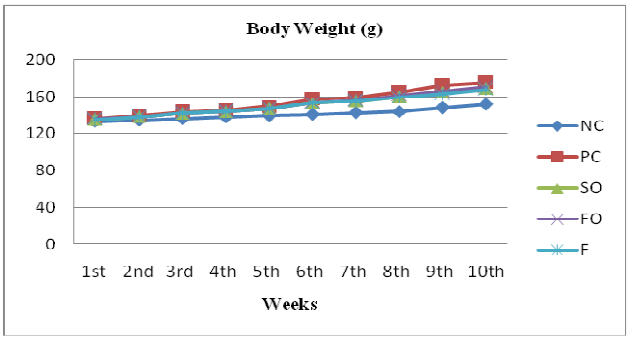

Fig. 4: Effect of Different Sources of Omega-3 Fatty Acids on Weekly Body Weight in PCOS induced rats

Table 1: Effect of Different Sources of Omega-3 Fatty Acids on Lipid Profile (mg/dL) in PCOS induced rats

Parameters	Treatments				
	NC	PC	SO	FO	F
Cholesterol	119.16±0.88[a]	161.33±0.88[d]	139.83±1.01[bc]	142.50±0.76[c]	137.50±0.86[b]
Triglycerides	93.17±0.44[a]	139.00±0.76[d]	117.67±1.45[b]	121.00±1.15[c]	117.00±1.15[b]
HDL	42.17±1.59[a]	26.50±1.15[d]	33.50±1.32[bc]	30.67±0.88[c]	35.67±1.45[b]
LDL	136.50±1.89[a]	166.83±0.44[c]	146.00±1.15[b]	147.33±0.88[b]	143.67±1.76[b]

Table 2: Effect of Different Sources of Omega-3 Fatty Acids on Hormonal Profile in PCOS induced rats

Parameters	Treatments				
	NC	PC	SO	FO	F
Testosterone (ngL)	0.72±0.04[a]	3.27±0.12[c]	1.06±0.07[b]	1.36±0.15[b]	1.26±0.12[b]
LH (mlU/mL)	5.63±0.34[a]	13.18±0.09[c]	11.75±0.12[b]	11.73±0.30[b]	11.03±0.52[b]
FSH (mlU/mL)	5.40±0.02[a]	2.76±0.07[b]	2.83±0.03[b]	2.80±0.10[b]	2.97±0.14[b]
Progesterone (ng/mL)	1.69±0.09[a]	0.12±0.006[b]	0.14±0.006[b]	0.14±0.02[b]	0.19±0.01[b]
Prolactin (ng/mL)	17.45±0.50[a]	25.48±0.40[b]	24.75±0.42[b]	24.95±0.41[b]	24.67±0.26[b]
Estrogen (pg/mL)	74.20±1.08[a]	55.73±0.81[b]	53.80±1.01[b]	54.13±0.76[b]	52.70±1.21[b]
Insulin (uIU/mL)	17.53±0.63[a]	29.73±0.93[c]	24.36±0.84[b]	25.17±0.79[b]	23.00±1.08[b]

Table 3: Effect of Different Sources of Omega-3 Fatty Acids on Weekly Blood Glucose (mg/dL) in PCOS induced rats

Weeks	Treatments				
	NC	PC	SO	FO	F
1st	97.15±1.16[a]	164.11±0.78[b]	162.43±0.53[b]	163.03±0.26[b]	161.83±0.60[b]
2nd	95.57±1.49[a]	165.67±0.88[b]	164.00±1.52[b]	164.70±1.13[b]	163.33±1.42[b]
3rd	96.78±1.35[a]	158.00±0.57[b]	156.50±0.76[b]	156.33±0.35[b]	155.4±0.87[b]
4th	94.60±1.53[a]	156.67±0.88[b]	154.33±1.20[b]	155.00±1.15[b]	153.33±0.88[b]
5th	94.58±1.47[a]	163.92±1.47[c]	146.22±0.61[b]	148.67±0.93[b]	146.0±0.58[b]
6th	89.13±1.04[a]	162.44±1.12[c]	143.33±1.45[b]	145.00±1.52[b]	142.00±0.58[b]
7th	93.83±1.48[a]	163.10±1.20[c]	144.00±1.52[b]	145.67±1.20[b]	142.33±1.85[b]
8th	95.33±1.45[a]	159.89±1.49[d]	146.33±1.76[bc]	147.73±0.81[c]	142.63±1.17[b]
9th	97.44±1.09[a]	162.67±1.02[d]	143.33±1.20[bc]	145.67±0.88[c]	140.83±0.44[b]
10th	96.52±1.75[a]	163.44±1.28[d]	144.67±0.88[bc]	145.83±1.17[c]	141.00±0.58[b]

Table 4: Effect of Different Sources of Omega-3 Fatty Acids on Weekly Body Weight (g) in PCOS induced rats

Weeks	Treatments				
	NC	PC	SO	FO	F
1st	134.56±0.61[a]	137.00±1.02[b]	136.70±0.46[b]	136.80±1.01[b]	136.37±0.88[b]
2nd	134.44±0.48[a]	140.40±0.56[b]	139.04±0.79[b]	139.56±0.89[b]	138.49±0.73[b]
3rd	135.88±0.87[a]	144.11±0.62[b]	143.47±0.47[b]	143.86±0.56[b]	142.45±0.59[b]
4th	137.68±1.17[a]	147.96±0.66[b]	147.14±0.69[b]	147.29±0.72[b]	146.84±0.70[b]
5th	139.19±1.24[a]	152.29±0.31[b]	149.85±0.45[b]	152.14±0.46[b]	149.88±0.95[b]
6th	141.05±1.31[a]	157.15±0.45[c]	153.11±0.67[b]	153.40±1.25[b]	153.33±0.67[b]
7th	142.77±1.12[a]	159.52±0.15[c]	155.23±0.82[b]	156.13±1.39[b]	155.23±0.75[b]
8th	144.11±0.86[a]	165.33±1.45[c]	159.95±0.48[b]	161.46±0.81[c]	159.59±1.42[b]
9th	148.29±0.41[a]	172.32±0.61[d]	164.69±1.00[bc]	166.30±0.44[c]	163.06±0.63[b]
10th	151.73±0.87[a]	175.26±0.32[d]	169.45±0.50[bc]	170.44±0.44[c]	167.92±1.06[b]

Negative control (NC), Positive control (PC), Synthetic Omega-3 (SO 250mg/kg/orally/daily), Flaxseed oil (FO 250mg/kg/orally/daily), Fish oil (F 250mg/kg/orally/daily)

DISCUSSION

Improvement in Lipid Profile

Adding a variety of omega-3 sources has shown beneficial effects on the lipid profile because it has enhanced the level of high-density lipoprotein (HDL) and decreased serum cholesterol, triglyceride, low density lipoprotein (LDL). The cause of lipid profile enhancement may be due to hepatic gene transcription associated with lipid metabolism such as PPAR (peroxisome proliferator-activated receptor), protein heterodimer heterodimer/ Max-like factor X heterodimer and sterol regulatory protein-binding element-1 modified with omega-3 fatty acids (Jump, 2008). Transport, synthesis and oxidation of fatty acids as well as aspects of intrahepatic glucose metabolism such as glycolysis and glucose transport to which transcriptional products of these genes are affected. Postprandial lipemia is also reduced by omega-3 fatty acids and can therefore reduce exogenous triglyceride in the liver (Kelley *et al*., 2007). In addition, lipoprotein lipase activity increases with omega-3 fatty acids, leading to triglyceride lipolysis increases and decreases plasma concentrations in triglycerides with concentrated liver circulation (Qi *et al*., 2008).

The addition of omega-3 fatty acids enhanced lipid profile observed by Mohammadi and Maryam, (2012). Cussons *et al*., noted a significant reduction of serum triglyceride levels in patients with PCOS after supplementation with EPA and DHA, but high-density lipoprotein-cholesterol concentrations (HDL-C), low density lipoprotein cholesterol (LDL-C) and cholesterol remain unchanged (Cussons *et al*., 2009). In individuals with visceral obesity, the substitution of omega-3 fatty acids resulted in significant serum triglyceride falls and increased HDL-C levels. The addition of fish oil reduced LDL-C serum levels in healthy people and in diabetic patients (Rashidi and Aryanpoor, 2007). The impact of fish oil on LDL, HDL, triglycerides and cholesterol was noted by Luka and Mohammed (2013). Their consequences showed that there was a significant increase in the levels of HDL while in total cholesterol, LDL and triglycerides was significantly decreased.

The cholesterol level with normal range is maintained with omega-3 fatty acid. In eating, the introduction of cholesterol increases the activity of the enzyme by more than 100% and the treatment of fish oil significantly reduces the activity of the enzyme, there has been a significant reduction after treatment with fish oil. Omega-3 fatty acids from fish oil can help improve high-level lipoprotein levels and lower triglyceride levels, diabetic patients can take advantage of eating food or taking supplements containing Eicosapentaenoic Acid (EPA) and Docoshexaenoic Acid (DHA). Alfa Linolenic Acid (ALA) cannot have a similar advantage as Eicosapentaenoic acid and docosahexaenoic acid because many individuals have no ability to effectively alter ALA in the form of omega-3 fatty acids that the body can use enthusiastically (Toth, 2009).

In the current study, flaxseed oil also has a significant influence on the lipid profile, but the effect is lower than the fish oil and the synthetic omega-3 source. Decreasing plasma cholesterol by adding flaxseed oil has been approved to reduce cholesterol levels. It is obvious that flaxseed oil can play an important role in reducing serum cholesterol in humans or in animals. Due to high cholesterol in the bile, which leads to the improvement of the intrahepatic cholesterol pool, it causes improved synthesis and cholesterol transport. Moreover, hepatic lipid accumulation is reduced by ALA rich diet and suppression of fatty acid synthesis and stimulation of β-oxidation (Murase *et al*., 2005). Ide *et al*., (2000) investigate that flaxseed oil may have its defensive effect as possible as a better substrate for peroxisomal and mitochondrial β-oxidation. All of these methods can explain improved lipid metabolism regulation in lipid oil for flaxseed oil.

Hormonal Profile

Hormonal imbalances that play a role in ovulation cause PCOS. In PCOS patients, follicle-stimulating hormone (FSH) levels are often reduced and levels of luteinizing hormone (LH) are increased. In the ovaries, follicles grow with fertile egg-induced FSH. Infertility occurs when the follicles do not mature and drop their eggs after long-term lack of FSH. After that, immature follicles in the ovaries expand into small cysts and PCO syndrome will occur. Too much estrogen, testosterone and androgen (male hormones) are produced in the body at high levels of LH, this inequality can cause pathological events in endometrial tissue and much widening of the uterus, which can lead to severe or irregular periods (Tena *et al*., 2011). Our results showed that FSH value was improved after omega-3 fatty acids treatment, but testosterone was significantly reduced ($P<0.05$).

The results of Nadjarzadeh *et al*., (2015) found that in PCOS women, the replacement of omega-3 had no effect on FSH concentration in eight weeks. Three months of application of omega-3 PUFA to the hormonal condition in twelve PCOS women have been studied but did not investigate any changes in FSH concentrations (Kuzmanov and Broughton, 2010). Karakas *et al*., study has shown the same consequences (Kasim-Karakas *et al.,* 2004). In their study, the concentration of LH and LH/FSH was significantly reduced after the intervention. Several studies did not investigate changes in LH concentration (Phelan, 2011) and LH/FSH ratio after intervention (Kuzmanov, 2010) as Karakas *et al*., studying the use of omega-3 PUFAs diet for three months. Azadeh *et al*. (2015) confirmed that after the addition of omega-3 prolactin concentrations did not significantly change. In this case, no similar study of changes in

prolactin has been found. The mean change in prolactin was not significant after eight weeks of research. Women with PCOS are at risk of metabolic disorders including inflammation, hyperinsulinemia and oxidative stress (Zheng and Li, 2016). There were only a few attempts to estimate the effects of omega-3 fatty acids in fish oil in women with PCOS on insulin metabolism parameters, but the results were not known. Our results were the results of Mohammadi *et al*. (2012), which confirmed that taking omega-3 fatty acids from fish oil for eight weeks at a dose of 4 g/day had a positive effect on the level of serum insulin and glucose uptake in PCOS patients. In inclusion, our effects were related to the results of other studies suggesting that the addition of omega-3 fatty acids from fish oil to young women causes decreased insulin concentrations (Navas-Carretero *et al*., 2009), reduced insulin concentrations in non-diabetics, reasonable patients with hemodialysis and hypertriglyceridemia. In another study, Hutchins *et al*., (2013) observed that in pre-diabetes patients with overweight or obese subjects with, flaxseed oil consumption for twelve weeks reduced insulin values and increased insulin sensitivity.

Lowering Blood Glucose

The results of this research were similar to data obtained from Gorety *et al*., (2017) results, as they noted that the important optimistic effect of omega-3 PUFAs supplementation on glycemic control (glucose and glycosylated hemoglobin) is needed but additional studies are needed to check this hypothesis because most of the beneficial effects are shown in epidemiological studies based on the fish diet that has been consumed for years.

Derosa *et al*., (2016) also noted that high doses of omega-3 PUFAs during 18 months were effective in reducing glycaemia and that aggravation of impaired glycemia by normoglycemia contributed to the slowing down of type II diabetes mellitus. Flachs *et al*., examined that beneficial effects of omega-3 PUFAs on glucose metabolism in humans depend on factors such as disease progression and ages (Flachs *et al*., 2014).

Rafraf *et al*., (2012) conducted omega-3 study that had the same consequences as omega-3 (240 mg/kg/ oral/daily) for 60 repeated days significantly reduced blood glucose concentration in the experimental group compared with PCOS. In the second study, daily supplementation of four capsules of omega-3 fatty acids over eight weeks resulted in a significant reduction in serum glucose, insulin and insulin resistance at the end of the study compared to baseline. In PCOS patients, omega-3 fatty acid supplementation had several positive effects on the state of glycaemia and may be useful in managing the metabolic problems of this syndrome.

Our results were also similar to Ramaballay and Shantal (2017) study that the addition of 100 mg/kg of body mass with PUFSs rich fish oil useful for improving tissue damage, as evidenced by the enzymatic activity and biochemical composition of these tissues. The significant decrease in glycosylated hemoglobin was observed after the supplementation of fish oil and free sugar along with 50% elevation in the insulin level confirmed the role of fish oil in regulating metabolism of glucose and rising action of insulin (Qujeq and Rezvani, 2007). This can be caused by a mechanism based on replacing fuel with improved glucose consumption and reduced fatty acid availability and improved insulin effect and may also be a cycle of glucose-fatty acid.

A small number of current researches have been done to check the beneficial effects of flaxseed on blood sugar levels. A Canadian study reported that there was 27% decrease in blood sugar levels in healthy persons who consumed 50 g of flaxseed in meals for four weeks after eating.

Body weight reduction

The results of this study were resembled to data obtained by the fact that the omega-3 fish oil supplement confirmed that it was effective to aid not only in weight loss but also loss of fat and belly fat loss in various trials (Crochemore *et al*., 2012). A significant decrease in glucose concentrations, triglycerides and insulin was confirmed after the ingestion of omega-3 fatty acids as a component of a weight-loss diet. In obesity patients, such an engagement was also carried out by the advancement of oxidative stress marker (Parra *et al*., 2008). However, in the adipose tissues of increased omega-3 PUFAs induced lipogenic gene down-regulation. Second, it might have been associated to alter the synthesis and storage of lipid because of the thoughtful decrease in lipemia related with omega-3 PUFAs. A considerable increased the in the high-density lipoprotein cholesterol and decrease in triglyceride levels after taking the moderate intake of fish oil supplementation. The accumulation of omega-3 fatty acids to an exercise also seems to enhance fat loss potential (Hill *et al*., 2007). Similarly, nutritionally balanced calorie-restricted diet with the incorporation of fish oil seems to improve weight loss potential.

Our outcomes were also similar to Kunesova *et al*., (2006) results who observed that individuals who consumed 2.8 grams of omega-3 fatty acid supplementation daily from fish oil, practiced a 1.5 kg weight loss in contrast to those consuming a placebo for three weeks clinical trial. Therefore, body composition can be improved by supplementing with omega-3 fatty acids but further weight/fat loss process can be accelerated after combining the supplementation of omega-3 fatty acids with calorie restriction and/or exercise. By improving metabolism and fat burning potential, omega-3 fatty acids may contribute to improved body composition. They also reduce appetite, which leads to the ingestion of fewer calories (Parra *et al*., 2008).

Vijaimohan *et al*., (2006) considered that consumption of 1g of flaxseed oil/kg of weight, rich in alpha-linolenic acid for sixty days reduced the body weight. The supplementation of flaxseed oil significantly decreased the increase in body weight gain. The antioxidant and hypolipidemic results may be responsible for the helpful effects of flaxseed oil on body weight gain. Bathena *et al*., (2003) studies on animals examined potential benefits of omega-3 fatty acid from flaxseed, reducing the retention of fat in the liver of genetically obese animals. It has been suggested that in the treatment of obesity, the flaxseeds may be used as a therapeutic strategy.

Therefore, most of the confirmation from studies in animals indicates that the dietary intake of omega-3 PUFAs may decrease the accumulation of body when exposed to a high fat diet and decrease body weight.

CONCLUSION

This article significantly contributed to the knowledge of PUFAs in PCOS and highlighted the role of these fatty acids in the treatment of metabolic and hormonal aspects of this condition. The present study was conducted to exert the effects of different sources of omega-3 supplementation in PCOS induced rats. From the results of the study it can be concluded that different sources of omega-3 have a positive impact on reduction lipid profile, hormonal profile and blood glucose as well as body weight loss. This research also presents prospects for future work.

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