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DIETARY INTERVENTION IN POLYCYSTIC OVARIAN SYNDROME – A BIBLIOGRAPHICAL REVIEW

Sara Calvo Pajares
European University of the Atlantic
saracalvop@gmail.com : https://orcid.org/009-0002-4334-3807

Abstract: The aim of the present study was to investigate which diet is the best option to treat polycystic ovarian syndrome (PCOS). A bibliographic review was carried out. Official web sites and documents were taken into consideration. Nevertheless, for the analysis of studies, just articles from indexed magazines were used. These articles were published between 2015 and 2022, and they were selected form the database PubMed. At the end, 19 articles were used. All of the discussed diets can be helpful to lose weight in case of overweight or obesity. In case of inflammation, the Mediterranean diet may be the best option because of its antioxidant value. When SOP coexists with diabetes, both the DASH diet and the ketogenic diet can be of great help. A low glicemic diet can be useful to improve the levels of sex hormones and the lipid profile in women with PCOS. More investigations and studies with bigger samples are needed to confirm the results shown in this work. However, the information exposed in this review points out that an anti-inflammatory diet, losing weight, in case it was necessary, and controlling the carbohydrates intake, is necessary to improve the symptomatology and health of women with PCOS.

Keywords: polycystic ovarian syndrome. Mediterranean diet. DASH diet. Ketogenic diet. Low glicemic diet.

REVISIÓN SOBRE LA INTERVENCIÓN DIETÉTICA EN SÍNDROME DE OVARIO POLIQUÍSTICO

Resumen: El objetivo del presente estudio es investigar cuál es la intervención dietética óptima en mujeres con Síndrome de Ovario Poliquístico (SOP). Para ello, se realizó una revisión bibliográfica. Se estudiaron documentos, páginas web oficiales y distintos artículos científicos. Para el análisis de estudios, fueron seleccionados distintos artículos que investigaban el efecto de una de las dietas de estudio en mujeres con SOP. Se tuvieron en cuenta un total de 19 artículos publicados entre 2015 y 2022, obtenidos de la base de datos PubMed. Como resultado se obtuvo que cualquiera de las dietas de estudio puede resultar de interés clínico para la pérdida de peso. La dieta mediterránea (DM) es interesante por su capacidad antioxidante. La dieta DASH y la dieta cetogénica (DC) han mostrado ser eficaces para controlar la glucemia en la población de estudio. La dieta de bajo índice glucémico (IG) puede mejorar el perfil de hormonas sexuales y otros parámetros analíticos, como el colesterol total o los triglicéridos. Son necesarios más estudios y con una mayor muestra para poder confirmar los resultados hallados. No obstante, la información expuesta en este artículo muestra que una pérdida de peso, en caso de que sea

necesario, una dieta antiinflamatoria y un control en la ingesta de hidratos de carbono son características a tener en cuenta para mejorar la sintomatología y la salud de mujeres con SOP.

Palabras clave: Síndrome de ovario poliquístico. Dieta mediterránea. Dieta DASH. Dieta cetogénica. Dieta de bajo índice glucémico

Introduction

Polycystic ovary syndrome (PCOS) is the most prevalent endocrine disease in women of childbearing age (1,2). These women usually present the following symptoms: anovulation or irregular menstrual cycles, hyperandrogenism, acne, hirsutism, ovarian follicles (fluid sacs), insulin resistance, excess visceral fat, infertility or obesity (2). In addition, about 20% of women in this population suffer from sleep apnea (3). Also, women with this condition suffer from systemic inflammation (4,5).

The syndrome is also associated with thyroid hormone malfunction (6). In the long term, this endocrine pathology may increase the risk of non-alcoholic fatty liver disease, cardiovascular disease (CVD) and endometrial cancer (2).

It is noteworthy that PCOS can significantly affect the quality of life of women who suffer from it (7,8), especially mental health (9). Depression (sometimes aggravated by hirsutism and infertility), acne and obesity are the three factors that worsen the quality of life of women with PCOS the most (7).

The etiology of the syndrome is not clear, but it is known to have a genetic and an environmental component (1). Some of the factors that can trigger this disease are hereditary factors, low birth weight, obesity, sedentary lifestyle or an unbalanced diet (1).

As for the dietary factor, some nutrients, such as sugar or saturated fats, can generate oxidative stress and inflammation, which in turn increase the risk of causing metabolic and hormonal dysfunction, for example, in the ovaries (10).

In addition to an unhealthy lifestyle, a prerequisite for PCOS is an excessive secretion of androgens by the female sex glands (11).

There is a theory that explains the origins of PCOS from an adaptive perspective. In times of food scarcity, where our ancestors lived situations with a high level of stress, there were certain genes and phenotypes that would be useful to favor survival. However, during the last century, most regions of the world have had unlimited access to food. These phenotypes, which once promoted an evolutionary advantage, are now a risk that increases the prevalence of obesity, cardiovascular disease and type II diabetes mellitus (11). As shown in Figure 1, the adaptations that have benefited our ancestors, such as insulin resistance, hyperandrogenism, increased energy reserves or less fertility, are now pathogenic (12).

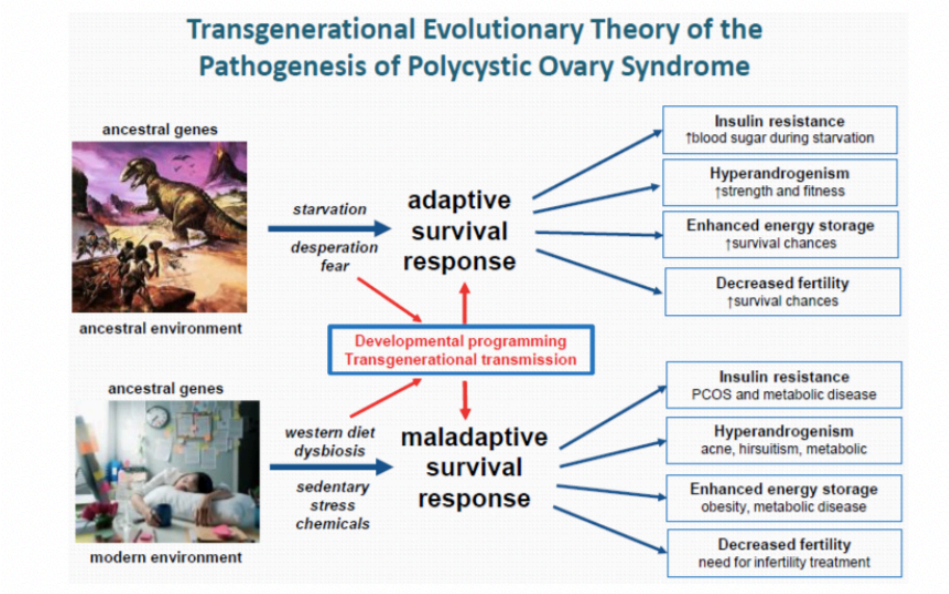

Figure 1: Theory of the pathogenesis of PCOS (13).

Diagnostic criteria

The Rotterdam criteria are mainly used to diagnose PCOS. Two of these three criteria must be met (8, 14):

- Oligo-anovulation: is the clinic of amenorrhea or oligomenorrhea. Oligoamenorrhea is the presence of less than 9 menstrual periods in a year or the presence of more than 3 menstrual periods/year of at least 38 days. That is, they are irregular menstrual periods (14). On the other hand, amenorrhea is the absence of menstruation for 3 or more menstrual periods (15).
- Hyperandrogenism: androgens are testosterone, androsterone and androstenedione. The physiological values of these sex hormones in women are: testosterone less than 0.6 ng/ml, androsterna less than 9 ng/ml and androstenedione less than 3 ng/ml. Reference values may vary depending on the laboratory. In clinical practice, the total testosterone value is the most commonly used to determine the presence or absence of hyperandrogenism (16).
- Have ovaries with a polycystic appearance: the diagnostic method for evaluating this parameter is ultrasound. To meet this third criterion, the ovaries must have a minimum of 12 follicles, between 2 and 9 millimeters each, or at least one ovary must have a volume greater than or equal to 10 ml (14).

On the other hand, there are two other methods to diagnose this disease. The Androgen Excess and PCOS Society states that hyperandrogenism and ovarian dysfunction must be present. This dysfunction may be due to alterations in ovulation and/or ovarian morphology. In contrast, the National Institute of Child Health and Human Development does not consider ovarian morphology as a diagnostic criterion, but does consider hyperandrogenism and ovulatory disorders (11).

Some experts point out that the term PCOS is not correct because it is not always necessary to have ovarian cysts to have the disease and having cysts does not indicate excessive production of androgens by the ovaries (11).

Treatment

Neither the U.S. Food and Drug Administration (FDA) nor the European Medicines Agency (EMA) has approved any specific drug to treat PCOS. For this reason, treatment should be individualized (11).

- Oral contraceptive pills: combine estrogens and progesterone. They restore the menstrual cycle and improve the symptomatology of acne and hirsutism (17). Promoting regular menstrual cycles is important for the prevention of endometrial pathologies, such as cancer (11).
- Metformin: the effects of metformin in regulating the menstrual cycle and improving signs of hyperandrogenism are mild to moderate (17). However, this drug is efficient in improving insulin resistance in women with PCOS, and is the most widely used treatment in cases of diabetes (11). Similarly, it aids in weight loss (17).
- Weight loss drugs: positive short-term effects have been seen in women with PCOS (11). Glucagon-like peptide-1 (GLP-1) is efficient in treating obesity in these women (17). However, the long-term repercussions that these drugs may cause in the study population are unknown (11).
- Bariatric surgery: Bariatric surgery is an intervention to be considered in obese patients with PCOS. Depending on the final weight after surgery, the characteristic signs and symptoms of the syndrome may reverse. This type of surgery improved the weight, menstrual cycles, and hormonal and metabolic profile of the women in the study by Hu et al. (18). According to these investigators, bariatric surgery should be a priority in obese patients with PCOS.

The criteria to be able to undergo this intervention are the same in the general obese population as in obese women with the syndrome (11). In order for a woman to be eligible for this operation, the body mass index (BMI) must be greater than 40 kg/m^2 or greater than 35 kg/m^2 and have another serious weight-related health condition (19).

- Other treatments to consider: cosmetics or retinol pills for acne or different shaving techniques for hirsutism (11). In addition, myoinositol-based supplements have been found to be effective in normalizing ovarian function in women with PCOS (20).

In conclusion, the treatment to be used will vary according to the symptomatology of each patient. The recommendation to combine several drugs such as oral contraceptives and metformin is increasingly widespread (17).

Before treating the syndrome with these drugs, it will be convenient to study possible changes in the patient's lifestyle. The first-line treatment in PCOS is lifestyle change (1,21, 22). The practice of physical exercise, a dietary treatment adapted to each patient, and reducing the percentage of fat; since up to 80% of women with PCOS are overweight or obese (23), are different alternatives that would improve the symptomatology of women with this syndrome (24).

Nutritional strategies to reduce overweight and obesity and improve insulin sensitivity will be beneficial in women with this disease (25). Some nutritional strategies that have shown some therapeutic interest in this pathology are the Mediterranean diet (MD), the Dietary Approach to Stop Hypertension (DASH), the ketogenic diet (KD) and a low glycemic index (GI) diet.

Likewise, achieving a healthy lifestyle can improve the quality of life of women with PCOS, even if weight loss is not achieved (8). Similarly, because not all women with the syndrome are overweight or obese, the impact that the diet may have beyond weight loss should be of clinical interest (26). Along the same lines, following a balanced diet is especially important in these women because, at the same BMI, women with PCOS have higher blood glucose and insulin levels than the general population (27). However, losing fat could be key to improving the metabolic and hormonal profile that leads to infertility in women with PCOS (28). Ultimately, a weight loss may be necessary to restore the menstrual cycle and thus fertility in the study population (29).

Current scientific evidence suggests that a well-adjusted and balanced diet is beneficial in improving insulin resistance, body weight and metabolic profile; and in preventing typical complications of the syndrome (26).

Mediterranean diet

DM was first defined by Ancel Keys with the 7-country study, who advocated that it was a diet high in vegetable oils and low in saturated fat (30). After its study, the diet has been defined in various ways, but some concepts that have been maintained over time are: that this style of eating provides a high consumption of olive oil, vegetables, fruit, legumes, nuts, whole grains, fish and seafood; a moderate consumption of dairy products, meat and red wine and a low consumption of sweets and saturated fats (30,31). DM is known for its effects in the prevention of CVD, type II diabetes mellitus, dementia and some types of cancer (32). This protective characteristic of DM is due in part to its ability to reduce visceral fat (31) and its anti-inflammatory role (5,27,33).

Adherence to DM is measured with the PREDIMED questionnaire, which consists of 14 simple questions that inquire about the dietary habits of the population (34). This questionnaire stems from the PREDIMED (prevention with Mediterranean diet) study (35), which was a clinical trial that sought to analyze the effect of the Mediterranean diet in the primary prevention of cardiovascular disease (36). In addition to the effects of the diet at the cardiovascular level, the results of the PREDIMED study show that good adherence to DM reduces the risk of type II diabetes, arterial hypertension, atrial fibrillation, cognitive impairment and breast cancer (36).

DASH diet

The acronym DASH stands for Dietary Approaches to Stop Hypertension (37). This diet was created by the National Institute of Health (38) at the end of the 1990s in the United States. The first time its effect was studied was with the study by Apple et al. (39), which consisted of comparing the effects of three different diets. The first was the control diet, the second a diet high in fruits and vegetables, and the third a combined diet, in which there was a high intake of fruits and vegetables and a minimal intake of fats. The conclusion of the study was that a diet high in fruits and vegetables and low in fat can significantly reduce blood pressure.

Four years later, Vollmer et al. (40) conducted a study not only to see the effects of the DASH diet on blood pressure, but also to find out the effect of sodium intake on this health parameter. The study participants were divided into two groups: control diet and DASH diet. Sodium intake was randomly assigned. As a result, it was observed that the DASH diet, together with a low sodium intake, was associated with a significant reduction in blood pressure.

The DASH diet does not include special foods, but simply makes several recommendations, including: eating fruits, vegetables and whole grains; including low-fat dairy products, chicken, fish, legumes, nuts and seeds and vegetable oils; and limiting the consumption of foods high in saturated fats, such as whole dairy products, fatty meat or palm oil, and foods high in simple sugars, such as sweets (41). This diet is intended to generate a high intake of potassium, calcium, magnesium and fiber and to reduce sodium intake to below 2.3 g/day (38).

This diet is mainly indicated for patients with hypertension (38), as it is directly related to a reduction in blood pressure (37). However, because it is a healthy dietary pattern, people without pathologies can also benefit from it. Similarly, patients suffering from diabetes, dyslipidemia or overweight can improve their health by following the DASH diet (38).

Ketogenic diet

The ketogenic diet was introduced in 1921 to treat epilepsy (42). It was thought that this high fat, adequate protein and low CH diet would be optimal for patients suffering from epileptic seizures, as it simulates the physiological situation that occurs during fasting. The ketogenic diet produces acidosis, dehydration and ketosis (as does fasting) but can be carried out for much longer (42,43).

This diet was widely used in children with epilepsy for two decades. However, with the appearance of new drugs, its therapeutic interest diminished and it was not until the beginning of the 21st century that the efficacy of this dietary intervention in the treatment of epilepsy was again emphasized (43).

The ketogenic diet consists of between 40 and 50 g of carbohydrates per day, which lowers hepatic and muscle glycogen and thus lowers blood glucose and insulin (29). This reduction of CH makes the body unable to use glucose as energy and, therefore, ketone bodies are produced from fatty acids (44). The main ketone bodies produced are acetone, acetoacetate and beta-hydroxybutyrate (BHB) (44). The latter is the most important marker of blood ketosis (21). BHB elevation occurs physiologically with fasting and with the ketogenic diet at values between 1 and 8 mmol/l (45). However, in situations of diabetic ketoacidosis, BHB can reach concentrations greater than 20 mmol/l (21).

In short, this diet can be an effective tool in people with type II diabetes mellitus, obesity and metabolic syndrome (46), as well as to treat other PCOS-related diseases, such as congenital hyperinsulinism or nonalcoholic fatty liver disease (44).

Low glycemic index diet

A low glycemic index diet is a nutritional intervention based on the elevation of blood glucose caused by food, i.e., its glycemic index (GI) (47). The glycemic index of a food can be between 0 and 100. Foods with a GI closer to 0 raise blood insulin more slowly than those with

a GI close to 100, which raise it faster. As shown in Table 1, foods can be classified into foods with a low, moderate or high GI (48).

Table 1

Classification of certain foods according to their glycemic index

Low GI foods	0-55	Barley, quinoa, pasta, carrots, apples, milk, yoghurt, pulses
Foods with moderate GI	56-69	Pita bread or rye bread, couscous, brown rice, raisins
High GI foods	70-100	Potatoes, white rice, most processed cereals, sugary drinks, sugar, watermelon, pineapple, etc

Note: taken from Mayo clinic

The GI can be affected by the stage of ripeness of vegetables and fruits or the method and point of cooking (48,49). It is also important to take into account the glycemic load (GL) of foods. This concept, which was introduced in 1997, defines the effect that a food has on blood glucose levels depending on the amount of CH it contains (50). A high GI food does not necessarily have to have a high GC. For example, fiber and water are two dietary components that will influence the GC of a food (49).

Low GI diets were born to treat diabetes (49). They reduce fasting insulin and HOMA-IR index more than high GI diets (51). Similarly, these nutritional strategies in diabetics can reduce BMI and improve lipid profile (52). However, some authors state that there is no significant difference between a high GI diet and a low GI diet in terms of fasting glucose concentrations (51).

These diets may be beneficial in helping to treat other pathologies. Increasing low GI foods and decreasing high GI foods within a healthy dietary pattern, with an appropriate distribution of macronutrients, provides benefits in cerebrovascular diseases, obesity and cancer, as well as in the control of dyslipidemia (49).

Method

The PubMed database was used mainly for the preparation of this literature review. In addition, the Google Scholar database and some official web pages were used. The search took place between December 2022 and March 2023.

The inclusion criteria for the studies analyzed were experimental and observational studies, whose population were women of childbearing age between 16 and 50 years, without associated pathologies, with or without dyslipidemia, with any BMI. Studies had to be published between 2015 and 2023 that looked for the relationship between PCOS and each of the study diets. The method used to diagnose the disease was not taken into account.

The exclusion criteria were systematic or bibliographic reviews on the subject treated, meta-analysis of data from studies and clinical trials that studied the effect of CH and PCOS in

a general way, without specifying the type of diet. We also excluded those studies whose population included animals or women with pathologies aggravated by the syndrome, such as type II diabetes mellitus or non-alcoholic fatty liver disease.

The following keywords were used: *Polycystic ovary syndrome. Mediterranean diet. DASH diet. Ketogenic diet. Low glycemic index diet.* Ultimately, 19 articles were used for the study analysis.

Results

For the reasons explained above, DM may be of interest in women with PCOS. Firstly, because of its anti-inflammatory capacity. In the study conducted by Wang et al. (10) found that a diet high in foods with a high dietary inflammatory index (DII) increased the risk of PCOS. As an example, some anti-inflammatory foods that make this diet an interesting intervention are fruits and vegetables or oily fish and nuts, rich in omega-3 fatty acids (10, 53).

Secondly, DM has great antioxidant power, as it is rich in fruits and vegetables and olive oil (54). In addition, this diet is low in sodium and high in potassium, thus promoting a good balance of these minerals and, therefore, good heart health (10).

Finally, Barrea et al. (27) observed that in women with PCOS, greater adherence to DM is associated with less clinical severity of the syndrome. Similarly, the same author and his research group conclude that adherence to this diet is one of the three most influential parameters for not aggravating cardiometabolic risk in obese women with PCOS (33).

According to M Azadi-Yazi et al. (55), the positive effect of the DASH diet in women with PCOS may be due to weight loss, as this would reduce blood testosterone levels. In line with these results, Cutillas-Tolin et al. (6) concluded that this diet could be effective in reducing BMI in women with PCOS.

On the other hand, another mechanism that explains the positive effect of the DASH diet in women with ovulation problems is that the calcium intake in this dietary pattern is high, and some metabolic problems of women with PCOS may be due to a poor metabolism of this mineral and of vitamin D. Lastly, this diet is rich in minerals such as magnesium, which increases the antioxidant capacity of the organism and, according to several authors, can improve insulin sensitivity (55,56). Likewise, the results of the study carried out by Asemi Z. et al. (56) show that the amino acid arginine, which is found in abundance in this diet, has a beneficial effect on insulin sensitivity.

In PCOS the ketogenic diet is still under study (59). The results obtained from the research carried out by Paoli et al. (58) suggest that this diet may be of interest due to the frequent glucose mismetabolization, as well as the activation of the protein compounds AMPK and SRT-1, which are responsible in some way for regulating energy metabolism (47, 48). Similarly, the results of the study by Magagnini et al. (45) show that a ketogenic diet reduced the HOMA index and insulin resistance. On the other hand, as some authors point out, CD can reduce hyperandrogenism, since it increases the transport of sex hormones by increasing sex hormone binding globulin (SHBG) and also increases circulating progesterone (44,45).

Similarly, according to Yang et al. (59), the ketogenic diet is of clinical interest in the study population because it is a method of fat loss. These results are supported by other studies, which show that after the intervention there was a reduction in BMI (29,45).

Finally, numerous investigations have concluded that a low glycemic index diet may be of therapeutic interest in women with PCOS (60,61). According to Hoover et al. (65), low-GI diets may reduce the risk and improve the signs and symptoms of PCOS. In this same study, it is stated that a low GI diet had a greater effect on satiety than a high GI diet (65). Other authors support the positive effect that this dietary pattern has on blood glucose control in the study population (62). It is worth mentioning that Szczuko (63) and his team observed that this diet had an effect on the reduction of insulin-like growth factor-1 (IGF-1). Numerous researchers have also written about the role of a low-GI diet in reducing body weight and various anthropometric values (60,61).

In short, the characteristics that can make a low GI diet beneficial in women with PCOS are that this diet provides an intake of complex carbohydrates, a high intake of fiber (especially soluble), a low intake of saturated fats and a high intake of unsaturated fats and a significant intake of vegetable proteins, reducing those of animal origin; it is rich in micronutrients (61).

Discussion

Mediterranean diet and PCOS

Part of the results of the study Barrea et al. (27) are contrary to those obtained by Moran et al. (53). The first investigator and his team suggest that those women with PCOS show lower adherence to DM than those women without the syndrome, while Moran et al. (53) state that sick women showed more adherence to a Mediterranean-style diet.

A key factor explaining the difference between the two results is the sample chosen for each study. The first study consists of Italian population, while the second one analyzes data from women in Australia. Moreover, only in the study by Barrea et al. (27) used the PREDIMED questionnaire, a tool mostly used to assess adherence to DM.

On the other hand, both studies affirm that DM can be a useful tool as a dietary treatment in women with PCOS. These results coincide with those of other studies (10,33). These studies affirm that DM can prevent an obese woman with PCOS from increasing her cardiometabolic risk associated with excess weight, as well as decreasing the inflammatory state typical of the syndrome.

However, in the case-control study by Ana Cutillas-Tolín et al. (6) no clear association was seen between a high DM adherence rate and an improvement in typical PCOS phenotypes. These results may be due to the fact that other healthy dietary patterns were also observed in this study, not comparing DM with a control diet.

DASH diet and PCOS

Of the 4 studies analyzed, 3 (55,56,57), which are experimental, support that there was a significant reduction in the body weight of those women who followed the DASH diet compared to those who followed a control diet. Similarly, in the study by Cutillas-Tolín et al. (6), which is observational, states that the DASH diet can improve BMI.

In addition to a reduction in weight, and therefore in BMI, M Azadi-Yazdi et al. (55) also observed a greater loss of fat mass in women following the DASH diet. Along the same lines, Asemi Z et al. (56) observed a significant reduction in waist and hip circumferences when following the DASH diet compared to the control diet.

As for the hyperandrogenism typical of the syndrome, it is unclear what effect the DASH diet may have. M Azadi-Yazdi et al. (55) obtained as a result of their study a reduction in androstenedione. However, in this research, no significant reduction in the free androgen index was observed, which was observed by Foroozonfard et al. (57). This difference may be due to the fact that Foroozonfard et al. (57) used the intention-to-treat principle, i.e., they included all study participants in the statistical analysis, even if they had not followed the diet correctly, whereas M Azadi-Yazdi et al. (55) did not.

None of the authors mentioned above observed a significant reduction in testosterone levels when comparing the study diet and the control diet. On the contrary, an increase in the SHBG protein complex has been observed (55,56, 57).

As for the parameters related to blood glucose levels, numerous studies show that these can be improved with the DASH diet. The group following the DASH diet showed a greater reduction in circulating insulin levels and HOMA index than the control group (55, 56, 57).

Ketogenic diet and PCOS

In the 4 experimental studies analyzed (58, 29, 45, 59) a reduction in body weight was seen in the study women. This is because all the ketogenic diets in the various studies were designed to be hypocaloric. In addition to weight loss, this diet has led to improvements in other anthropometric parameters: decrease in waist circumference, hip circumference and fat mass.

While in the study by Yang et al. (59) stated that a ketogenic diet can reduce subcutaneous and visceral fat in women with PCOS and hyperuricemia without negatively affecting muscle mass, in the study by Cincione et al. (29) observed a small but significant reduction in the amount of muscle mass after the ketogenic diet. Similarly, a difference in blood lipid lowering has been seen in these two studies. In the study by Yang et al. (59) total cholesterol, LDL and blood triglycerides did not decrease after the ketogenic diet significantly. In the Cincione et al. (29) yes. Both differences, both the loss of muscle mass and the reduction in blood lipids, may be due to the fact that in the second study a very low calorie diet was followed and in the Yang et al. study the diet was less restrictive.

The three uncontrolled trials analyzed (6,31,52) show an improvement in terms of biochemical parameters related to blood glucose after following a hypocaloric ketogenic diet. A reduction in the HOMA-IR index of insulin resistance was seen.

Regarding hormones, a decrease in antimullerian hormone has been seen, as well as an increase in progesterone and SHBG (58, 29, 45) and a decrease in testosterone in those studies in which the concentration of this hormone was analyzed (58, 29, 45).

Finally, it is worth mentioning the positive effect of this diet on women with ovulation and fertility problems. Of the 17 women participating in the study by Cincione et al. (29), 5 recovered their menstrual cycle after years of amenorrhea, 12 managed to have a regular cycle and, of these 12, 5 managed to become pregnant after having previously failed.

Low glycemic index diet and PCOS

All experimental studies in which the effect of a low-GI diet on body weight in women with PCOS has been observed (60,61,62,63) have shown significant weight loss after such an intervention. Similarly, the case-control study of Panjeshahin et al. (64) suggests that those women who followed a high GI diet had significantly higher BMI.

Regarding changes in parameters related to glucose metabolization after following a low GI diet, the evidence is inconclusive. In the studies carried out by Hoover S.E et al. (65) and Szczuko M et al. (63) in which these variables were analyzed, lower basal glucose and insulin were seen after performing the low GI diet. However, the same investigator in another study (61) saw that there was no significant difference in terms of insulin and blood glucose decrease at the end of the study weeks. It is worth mentioning that, in this study, a small improvement in insulin and blood glucose was seen.

According to Szczuko M et al. (61), it is likely that the improvement in glucose metabolization parameters was not significant in this study because the participants did not comply with the physical exercise recommendations.

On the other hand, the sex hormone profile may be improved by following a low-GI diet in women with PCOS. Szczuko M et al. (63) observed a positive correlation between IGF-1 protein (polypeptide hormone that increases with a low GI diet) and SHBG concentration. Similarly, Shishehgar F et al. (62) observed a significant increase in this protein after dietary intervention. This increase directly improves the hormonal profile of these women. This same study also observed a reduction in circulating testosterone (62), data supported by other research (63) but contrary to those provided by the results of Szczuko et al. (61).

Continuing with hormones, Hoover SE et al. (65) observed that following a low GI diet reduced ghrelin levels more than following a high GI diet (65). These results are of particular interest, as numerous investigations suggest that women with PCOS may have altered hunger and satiety mechanisms. It may be that by following a low GI diet and reducing ghrelin these women achieve better weight control.

Finally, other biochemical parameters such as total cholesterol, LDL and triglycerides are also significantly reduced after following a low GI diet (60,61,62,63). However, in the case-control study by Panjeshanin et al. (64) related good adherence to a low-GI diet to having elevated total cholesterol. As the authors themselves state, this may be due to the fact that cooking methods were not taken into account. Continuing with other blood lipids, Szucko et al. (61) did not obtain significant improvements in HDL levels in the participants; such improvement was observed by this author and his team in another investigation (63), as well as by Lagowska K and Drzymala-Czyz S in their study (60). Again, as the authors themselves

state, it may be that the increase in HDL was not significant in the first study by Szucko et al. (61) because the women did not comply with the recommendations of practicing physical exercise at least 3 times a week.

The present work has some limitations. The total samples of most studies are less than 60 women, i.e., the samples are somewhat small considering the prevalence of PCOS. On the other hand, the studies analyzed on DM and PCOS deal, for the most part, with adherence to this dietary style. Therefore, how PCOS symptomatology is influenced by following DM was not studied in depth in these investigations.

On the other hand, a strength of this review is that no other literature review comparing the 4 study diets analyzed here was found. Likewise, articles whose samples had any BMI were included in this study. That is, no study has been excluded because of the weight of the women in the sample, so that the general results can be extrapolated to any woman with PCOS who does not have any other serious health condition.

Conclusions

It has been shown that the four study diets: DM, DASH, DC and a low GI diet can be beneficial in treating PCOS, depending on the context and characteristics of each woman.

In case the woman needs to lose weight, any of the diets analyzed in this literature review, as long as they are properly designed and generate a caloric deficit, could be effective tools. However, in case of obesity or marked overweight, a very low calorie CD can be used as a first intervention. After achieving a rapid initial fat loss, it may be useful to follow a more flexible diet, such as the Mediterranean diet or DASH, as these dietary patterns allow better adherence. However, HCs should continue to be controlled, avoiding simple HCs.

Following this line, it is noteworthy that weight loss in women who need it can itself generate improvements in both cardiometabolic health and symptomatology in women with PCOS, regardless of how it has been achieved. On the other hand, due to the antioxidant power of DM, this dietary pattern may be of great help in women with chronic inflammation. For improving fertility in women with PCOS, DC has shown some efficacy. Likewise, women who suffer markedly from hyperandrogenism may benefit from a CD, as this diet has been found to be effective in improving the hormonal profile of women with PCOS. In short, more studies with more participants are needed to further investigate the effect of diet on PCOS.

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