



Role of Lifestyle, Diet, and Exercise in the Management of Polycystic Ovarian Syndrome

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Amy Plano

Key Points

- Lifestyle modification has been shown to be effective in improving body weight as well as the metabolic, reproductive, and psychological features of polycystic ovarian syndrome (PCOS).
- Abnormalities in insulin-induced glucose optimization consequently resulting in hyperinsulinemia are well known in women with PCOS.
- Hyperinsulinemia can promote fat storage (and hence weight gain), increase cravings for carbohydrates, cause hypoglycemia, and make weight loss challenging.
- Long term these metabolic adaptations can increase an individual's risk for developing obesity, type 2 diabetes, hypertension, and cardiovascular disease.
- Hyperinsulinemia responds remarkably well to weight reduction through diet, exercise, and lifestyle modifications.
- Therefore, diet therapy is without question a most important and effective management strategy managing the symptoms of PCOS.
- While there is much debate about the optimal balance of macronutrients that is uniformly beneficial to women with PCOS, evidence supports that both the quality and quantity of dietary carbohydrates are important for a woman with PCOS.
- Evidence does not support the benefits of drastically reducing or eliminating dietary carbohydrates in this population.
- Instead, a diet with an emphasis on consuming a moderate amount of unrefined carbohydrates qualified as low to medium on the glycemic index scale is supported.
- Additionally, the diet should be low in saturated fat and sodium and high in fiber from whole grains, fruits, and vegetables and modest in lean sources of protein.
- A diet of this quality can improve short- and long-term symptoms of PCOS, as well as decrease the risk of chronic diseases associated with insulin resistance.

A. Plano (✉)

The Plano Program Nutrition Center, Orange, CT, USA

- Given their propensity to experience reactive hypoglycemia, women with PCOS are an ideal population to benefit from frequent meals and snacks.
- Physical activity can reduce insulin levels, improve insulin sensitivity, and optimize lipid profiles as well as improve self-esteem, *decrease* depression, and *reduce* anxiety in women with PCOS.
- Regular exercise must be encouraged and incorporated in the management paradigm of PCOS.

Introduction

With insulin resistance and compensatory hyperinsulinemia central to the pathogenesis of polycystic ovary syndrome (PCOS) and obesity and dyslipidemia being common accompaniments to the clinical picture, lifestyle interventions aimed at reducing insulin levels and improving insulin sensitivity are critical to the overall management of this disorder. While there is strong agreement that a hypocaloric diet is beneficial for overweight and obese women with PCOS, there is much debate about the balance of dietary macronutrients that could be construed as optimal for this population. The inclusion of regular exercise has also demonstrated a positive impact on metabolic and clinical parameters in women with PCOS. Management strategies must prioritize body weight optimization and improving insulin sensitivity. This chapter provides an overview of lifestyle interventions that can successfully address the spectrum of metabolic derangements that are commonly encountered in PCOS and are modifiable through dietary modification and regular physical activity.

Why Diet Makes a Difference in Women with PCOS

Abnormalities in insulin-induced glucose utilization are well recognized in PCOS [1–3]. The inability of the secreted insulin to optimally drive the cellular machinery through glucose transportation and utilization results in a reactionary increase in pancreatic output of insulin; higher levels of insulin are thus needed to facilitate insulin actions, a phenomenon called *insulin resistance*. In the presence of hyperinsulinemia and impaired insulin signaling, energy efficiency is impaired and glucose, instead of being utilized as fuel, gets diverted towards lipogenesis and hence fat storage [4]. Hyperinsulinemia, in turn, encourages fatty acids to be deposited as body fat while also inhibiting its release from fat stores. The metabolic processes are subtle and yet translate into progressive weight accrual despite reportedly regular physical activity and even caloric restriction. Over time, these processes can exhaust the pancreatic beta cells; ability to adequately maintain euglycemia is thus impaired, setting a stage for the development of type 2 diabetes, a disorder commonly seen in women with PCOS [5, 6]. Adiposity worsens the innately disturbed insulin signaling. Body mass excess is evident in almost two-thirds of women with PCOS and is recognized to worsen several features of PCOS, such as

hyperandrogenism, hirsutism, infertility, and pregnancy-related complications. Insulin resistance is associated with an increased risk for several other disorders, including hypertension, dyslipidemia, elevated markers of inflammation, endothelial dysfunction, and heart disease. Impaired glucose tolerance or type 2 diabetes develops by the age of 30 in 30–50% of obese patients with PCOS [5, 6].

Progressive weight gain, cravings for carbohydrates (CHO) and sweets, and symptoms of hypoglycemia (such as dizziness, fatigue, shakiness, irritability, headaches, postprandial exhaustion, and somnolence) are common in women with PCOS. Episodes of hypoglycemia are typically encountered when an individual goes long periods of time without eating. More typically, however, patients manifest features of *reactive hypoglycemia* following ingestion of refined carbohydrates, e.g., candy or a large serving of sweets. An outpouring of pancreatic insulin in response to an abrupt rise in glucose, with lingering hyperinsulinemia and delayed onset of insulin action, is contributory to a precipitous drop in circulating blood glucose levels. A few hours after ingestion of a CHO load, instigating cravings for sweets ensues. Indeed, many women with PCOS report strong, almost compulsive, uncontrollable urges for “sweets” and CHO-rich foods [7–9].

Reassuringly, insulin resistance of PCOS responds remarkably well to weight reduction through dietary change, exercise, and improved lifestyle [10]. An optimal diet for a woman with PCOS must encompass several facets. It must be calorie appropriate to support the specific needs of the particular woman (weight maintenance, weight loss, or weight gain). Proportioning meal size and ensuring a timely intake of nutritionally balanced snacks and meals are strategies that can successfully abort the viscous cycle of insulin resistance-driven carbohydrate cravings. Lowering of dietary sugar load and choice of complex dietary CHO reduces the postprandial excursion in serum glucose and hence lessens the magnitude of insulin secretion in response to dietary load. Reducing postprandial insulin levels has demonstrated an increase in fat oxidation for several hours following a meal and reduced hunger and hence predisposition to overeating and weight gain [5]. A balance in respective amounts of dietary carbohydrate, protein, and fat can further ensure homeostasis while mitigating insulin resistance. *Eating patterns in combination with lifestyle modification that include consistent exercise that support lower insulin levels and should be central to the treatment of the symptoms of PCOS.*

Dietary Carbohydrates

The primary role of dietary CHO is to serve as fuel. Carbohydrates in diet are almost exclusively of plant origin. Milk is the only animal-derived food that contains a significant amount of CHO. Fruits, vegetables, whole grains, and legumes (beans, lentils, peas) are major sources of whole, unprocessed CHOs; fruit drinks, soft drinks, cookies, ice cream, and candy bars too are examples of dietary CHO, albeit these latter represent more processed and less nutrient-dense versions of carbohydrates. Although foods containing protein and fat affect insulin secretion, ingested CHO content has a more pronounced effect on pancreatic insulin release and

circulating insulin levels. The rapidity of CHO breakdown and gastrointestinal absorption following ingestion depends on the *type* of ingested CHO. The more refined and processed the CHO content of a meal, the less work the body has to exert to digest and absorb the nutrient. The glycemic effect (also called the *glycemic response*) refers to the effect a particular food has on a person's blood glucose and insulin response. The more refined varieties of dietary CHO evoke a higher glycemic response, and this phenomenon represents the basis for how many CHO-containing foods are classified.

Glycemic Index of Foods

The glycemic index (GI) of foods is a numerical system of measuring how much of a rise in circulating blood sugar the food triggers – the higher the GI number, the greater is the expected excursion in blood sugar response following ingestion of that particular food. Foods containing CHOs that are broken down easily and raise the blood sugar quickly are referred to as *high glycemic* foods; both glucose and white bread are currently considered reference foods with a GI of 100. Foods with a GI index between 70 and 100 are considered *high*, whereas values between 55 and 70 and <55 are deemed of medium and low GI index value [10, 11]. The fiber content of various edibles influences their respective GI index; higher dietary fiber content slows the rapidity of glucose absorption and hence offers a more controlled rise in blood sugar levels. Food items containing a high fiber content (>5 grams/serving) are classified as *low glycemic* foods, which also promote an increased level of satiety, thus helping control appetite and decrease hunger, and are ultimately helpful for weight management. Table 14.1 presents GI values for common food items.

There are many proponents of a low-GI diet as a means to improve insulin sensitivity and possibly improve the androgen profile of women with PCOS [12, 13]. Because the majority of women with PCOS demonstrate marked compensatory hyperinsulinemia after CHO ingestion, there may be specific metabolic and cardiovascular benefits of consuming low-GI value diet. However, while numerous studies have assessed the impact of a low-GI diet in the general population (non-PCOS women), few studies have specifically examined the role of a low-GI diet on women with PCOS [14–16].

In a 2010 study performed by Marsh et al., researchers compared the changes in insulin sensitivity and clinical outcomes after similar weight losses after the consumption of a low-GI diet compared with a conventional healthy diet in women with PCOS [16]. Both diets were designed as reduced-energy, moderate-to-high fiber with similar macronutrient distribution. Only the quality of carbohydrates (i.e., GI) varied between the two diets. Overweight and obese women with PCOS were assigned to one of two groups: (1) an ad libitum low-GI diet or (2) a macronutrient-matched healthy diet. Both groups were followed for 12 months or until they reached a 7% weight loss. With only a modest weight loss of 4–5% of body weight, the group of women following the low-GI diet experienced a threefold greater improvement in whole-body insulin sensitivity. In addition, women following the

Table 14.1 Glycemic indices of common dietary items

<i>High glycemic index foods</i>
Watermelon
White bread
Certain cereals (Cheerios, Corn Flakes, Rice Krispies)
Mashed potatoes
Honey
Soft drinks
<i>Moderate glycemic index foods</i>
Watermelon
Sourdough or rye breads
Cream of wheat and instant oatmeal
Orange juice
Pineapple
<i>Low glycemic index foods</i>
Bran cereal
Old-fashioned oatmeal
Peaches
Lentils
Milk
Sweet potatoes

low-GI diet demonstrated improved menstrual cycle regularity (95%) versus those women following a conventional healthy diet (65%). While not a long-term study, this research nonetheless supports the capacity of dietary carbohydrates to increase postprandial glycemia, which ultimately when manipulated may be an important consideration for managing the symptoms associated with PCOS.

Another study performed by Mehrabani et al. examined the impact of the glycemic load on overweight and obese women with PCOS [17]. A total of 60 overweight and obese women with PCOS were recruited and randomly assigned to 1 or 2 hypocaloric diet groups for a single-blind clinical trial. Group 1 included a conventional hypocaloric diet (CHCH – with 15% of dietary calories coming from protein). Group 2 included a modified hypocaloric diet (MHC) with a high protein, low glycemic load (30% of daily energy from protein plus low-glycemic load foods selected from a list). Both diets were prescribed via 12-weekly counseling visits. While weight loss and androgen reduction were similar between both diet groups, the group adhering to the MHCD presented with a significant reduction in insulin level and an overall decrease in high-sensitivity C-reactive protein when compared with the conventional diet. While research in this area does appear promising, more research regarding the long-term efficacy of low-GI diets in this population is clearly needed.

Limitations of Using the Glycemic Index for PCOS Patients

Despite the potential dietary advantages noted above for metabolic benefit in chronically hyperinsulinemic and insulin-resistant populations, an overenthusiastic focus on dietary GI has several disadvantages worth noting. First, in assigning a numerical value to a food item, GI assumes the food is eaten alone, which is often not the case. When foods are eaten in combination, indices of consumed

items may influence the overall GI of the meal. Dietary fat and fiber slow the process of meal digestion and, therefore, can lower the GI of an individual food item. For example, an apple eaten alone produces a rapid rise in blood glucose. However, the rise is not as substantial if you add a tablespoon of natural peanut butter; the apple is digested at a slower rate.

The GI of the food is also affected by its acidity, ripeness, processing, the length of storage, cooking methods, and its variety. For example, a yellow banana has a lower GI than a brown banana. Fully cooked pasta has a lower GI than al dente pasta; boiled potatoes have a lower GI than a baked potato. Even beverages such as soymilk, depending upon the brand, can dramatically vary in the CHO content and, hence, GI.

Lastly, the GI does not tell us anything about the nutritional content of the food. *A low-GI food does not equate to a healthy food.* Also, just because a particular food has a low or moderate GI does not mean that food can be consumed in abundance. The GI simply tells us how quickly a particular CHO affects blood glucose levels and thus pancreatic insulin response to the consumed food. Therefore, by strictly avoiding certain foods with high GI, individuals may deprive themselves of some nutritious foods. For example, **watermelon has a GI of 72 and is considered a high-GI food**, while a chocolate bar has a GI of 68 and potato chips have a GI of 58, making classifying them both as moderate-GI foods. It is evident watermelon is nutritionally superior choice to a chocolate bar or potato chips. Therefore, while the GI deserves some consideration, it should not be the only criterion when selecting appropriate meal choices. The total amount of dietary CHO, the food's caloric density, the amount and type of fat, dietary fiber, and salt contents are additional dietary considerations that merit attention.

Guidelines for Dietary Carbohydrate

As discussed, diets high in CHO and refined and processed forms of CHO are particularly detrimental for the insulin-resistant PCOS population. However, evidence does not support the benefits of drastically reducing or eliminating carbohydrates in the diet either [18, 19]. Given that the majority of women with PCOS have underlying issues with insulin resistance, the increased likelihood of obesity, and risk factors for developing type 2 diabetes, a diet that is moderate in CHO with a focus on low-GI foods is best suited for this population. Women with PCOS should aim for around 40% of their total calories coming from CHO (Table 14.2). This amount is appropriate to optimize blood glucose levels while still providing many of the benefits of low-GI diet. For a woman consuming 1500 kcals per day, this would equate to a maximum value of 150 g of CHO spread consistently throughout the day (e.g., 20–30 g of low-GI CHO with breakfast, 35–40 g of low-GI CHO with lunch, and 30–35 g of low-GI CHO with dinner). The remainder should be consumed in two to

Table 14.2 Recommended daily carbohydrate consumption for women with PCOS based on daily caloric intake

Daily caloric level	Daily maximum carbohydrate level (g/day)
1400	140
1500	150
1600	160
1700	170
1800	180
1900	190
2000	200

three low-GI snacks spaced equally between the three meals. A specific meal plan fitting these criteria is provided later in this chapter.

Fruits and PCOS

All fruits in their natural form are nutritious, and regular consumption should be encouraged by women with PCOS. Despite the “healthy” connotations, all fruits are predominantly composed of CHOs. Typically, one serving of fruit contains about 15–20 g of CHO, no protein or fat, and 60 calories. Therefore, while fruit (quantified as one small whole fruit such as apple, orange, or banana; $\frac{3}{4}$ to 1 cup of cubed fruit such as melon, strawberries, or grapes; or $\frac{1}{4}$ cup of dried fruit such as raisin, prunes, or apricots) contains many positive benefits, such as fiber, vitamins, minerals, and antioxidants, an individual with PCOS needs to be mindful of the quantity consumed; women should aim for consuming two servings of fruit per day.

Given fruit items are poor in fat or protein, they may be best paired with a lean protein choice or modest amount of fat, such as low-fat cheese, yogurt, or nuts, to stabilize blood sugar and promote increased satiety. Women with PCOS should particularly avoid fruits in canned heavy syrup; when purchasing canned fruit, the words “extra light syrup” and “packed in juice” are optimal.

Dried fruit can be a nutritious addition to the diet of an individual with PCOS. Dried fruit is high in fiber, vitamins, and minerals such as potassium and iron as well as antioxidants. However, due to the fact dried fruit has been dehydrated, the natural sugars and calories are much more concentrated compared to those found in fresh fruit. In addition, some manufacturers add sugar in the processing. Therefore, while women with PCOS do not need to avoid dried fruit, they do need to be mindful of the quantity they consume just as they should with all fruits.

All fruit juices represent a concentrated source of sugars and low amount of fiber and are best avoided, as even small amounts can spike insulin, making weight loss difficult. It is always preferable to choose whole fruit over fruit juice, even if the juice label states “100 percent juice.”

Vegetables and PCOS

Vegetables are high in fiber and abundant in vitamins, minerals, and antioxidants. There are two main categories of vegetables: non-starchy and starchy vegetables. Non-starchy vegetables include spinach, lettuce, broccoli, green beans, onions, mushrooms, zucchini, and peppers and promote satiety. They are low in calories and in CHO and contain fiber and numerous vitamins, minerals, and antioxidants, so an individual can consume them without worrying about gaining weight or worsening insulin resistance. Women with PCOS can typically consume non-starchy vegetables in unlimited amounts and should aim for *at least* three servings of non-starchy vegetables (each serving defined as one-half cup of cooked vegetables, one cup of raw vegetables, or one 8 ounce cup of vegetable juice) daily.

Starchy vegetables have a higher CHO content and, therefore, a more significant impact on insulin levels than the non-starchy ones and include corn, peas, winter squashes, plantains, and all types of potatoes. Although excursions in insulin levels are much higher following ingestion of starchy vegetables, the goal however is not to eliminate starchy vegetables from the diet. One serving of starchy vegetables contains 15 g of CHO, 0–3 g of protein, 0–1 g of fat, and 80 calories in contrast to approximately 5 g of CHO, 2 g of protein, and 25 calories per non-starchy vegetable serving. Therefore, women with PCOS when consuming starchy vegetables should practice caution.

Dietary Fiber and PCOS

Dietary fiber is the indigestible part of plant-based foods and passes through the gastrointestinal tract in its original form. In spite of the numerous benefits of consuming adequate fiber, research supports that women with PCOS consume a diet lower in fiber compared to their non-PCOS counterparts [20, 21]. Fruits, vegetables, nuts, seeds, beans, and whole grains all contain fiber. In the stomach, fiber content of consumed food conveys a feeling of fullness, delays gastric emptying, and promotes a feeling of satiety. Additionally, in appropriate amounts, dietary fiber has been demonstrated to have a cholesterol-lowering effect [22, 23]. The products of bacterial digestion of fiber in the colon are absorbed into the body and may inhibit the body's production of cholesterol as well as enhance the clearance of cholesterol from the blood. Lastly, fiber has been demonstrated to improve the way the body handles glucose by slowing the digestion and absorption rate of CHO. This promotes a slower, more stable rise of blood glucose and helps prevent the symptoms of reactive hypoglycemia and reactionary sugar cravings that are commonly experienced by women with PCOS [24]. In addition, the more gradual the release of blood glucose, the longer it will take for the body to feel hungry again.

Box 1 Strategies for Optimizing Dietary Fiber Intake

- For breakfast, choose a high-fiber breakfast cereal. Look for cereals with at least 5 or more grams of fiber per one cup serving.
- Add a few tablespoons of unprocessed wheat bran, flaxseed, or chia seed to your favorite cereal.
- Consume breads that list the words “whole wheat,” “whole-wheat flour,” or other whole grain as the first ingredient on the label.
- Purchase brands of bread with at least 3 g of dietary fiber per slice.
- Add beans such as lentils, black-eyed peas, lima beans, great northern beans, and chickpeas to your diet.
- Sprinkle crushed walnuts or slivered almond into your hearty salads.
- Snack on raw non-starchy veggies like celery, cucumbers, and peppers by themselves or dipped in a bean dip like hummus.

Recommendations for Fiber and PCOS

Women with PCOS should aim to consume 25–30 g of fiber per day. Products containing 3 g or more per serving are considered a good source of fiber, whereas diets containing 5 or more grams of fiber per serving are considered as *high* fiber source. *Just because a food label may state “100% wheat” or “multigrain” does not mean it is a good source of fiber.* Products that have the words *whole wheat, whole oats, whole rye, bulgur, graham flour, oatmeal, or wild rice* listed as the first ingredient on the food’s label represent a high-quality source of fiber. Table 14.3 offers tips for including more fiber in the diet.

Protein

Protein has many vital roles in the body. About 20% of our total body weight is protein. The body uses protein for building and maintaining tissues, to make important enzymes, hormones, neurotransmitters, tendons, ligaments, antibodies, and other body chemicals. Women with PCOS should do their best to select lean rather than high-fat sources of animal protein. Women with PCOS are advised to substitute a portion of their dietary CHO for protein as a strategy to reduce overall dietary CHO content. Protein takes longer than CHO to digest, and dietary protein content confers a sense of satiety; thus, inclusion of lean protein in meals and snacks can improve the overall insulin response in women with PCOS [25]. An optimal intake for protein for women with PCOS would be between 25% and 30% of total calories consumed. For a woman following a 1500-calorie diet, this would equate to around 100–110 g of protein per day, spread equally among meals and snacks. A helpful

hint is every 1 ounce of lean protein is equal to 7 g of protein. Therefore, a 4 ounce chicken breast (equivalent in size to small computer mouse or deck of cards) contains roughly 28 g of protein. By consuming regular amounts of protein throughout the day, women with PCOS can help stabilize blood sugar and prevent hypoglycemia and subsequent cravings.

Box 2 Considerations When Choosing Dietary Protein Sources

- 3 ounces of protein is equal to the size of the palm of your hand or a deck of cards.
- Fish and shellfish, fresh, frozen, or canned in water, are excellent protein choices. Experts recommend heart-healthy benefits of consuming at least two servings of fish per week.
- Meat, chicken, and fish are all excellent sources of protein, as well as iron, zinc, and vitamin B₁₂. Women with PCOS should focus on the low-fat varieties as well as the leanest cuts of meat, such as the following:
 - Flank steak, round steak, sirloin, tenderloin, or extra-lean ground beef (90% lean or greater).
 - Lean ham, Canadian bacon, pork tenderloin, and center-cut loin pork chops.
 - Chicken, turkey, or game hens without the skin; extra-lean ground turkey or chicken breast.
 - At the deli counter, select low-fat, low-sodium options such as lean ham, turkey, chicken, or lean roast beef.
 - Eggs are also an excellent protein choice. Choose organic, cage-free eggs whenever possible. They are higher in omega-3 fatty acids. Egg substitutions, although they do not supply any of the healthy fats or many of the beneficial nutrients found in whole eggs, can also be consumed. One-quarter cup of egg substitute is equal to one egg.
 - Beans are a good source of fiber as well as good source of protein. All beans do contain carbohydrates, so it is important for women with PCOS to be mindful of the quantity. One-quarter cup of any of the following is equivalent to 1 ounce of meat: kidney beans, lentils, chickpeas, white beans (cannellini), black beans, or pinto beans.

Lipid Abnormalities in PCOS and Relevance of Dietary Fat

Abnormalities in lipid profile are encountered in almost two-thirds of women diagnosed with PCOS [26]. Hyperandrogenemia, central obesity, insulin resistance, and hyperinsulinemia acting in conjunction are recognized as mechanisms for the observed spectrum of dyslipidemia in women with PCOS. Lipid abnormalities commonly encountered in PCOS patients are similar to those observed in diabetics and include elevated levels of low-density lipoprotein (LDL) cholesterol and triglycerides and lower levels of high-density lipoprotein (HDL) cholesterol [27].

Hyperinsulinemia and hyperandrogenemia have been thought to cause adipocytes to undergo increased catecholamine-induced lipolysis and release of free fatty acids (FFA) into the circulation [27]. Increased FFA in the liver stimulates the secretion of triglyceride-rich very-low-density lipoprotein (VLDL), ultimately contributing to the commonly encountered hypertriglyceridemia in this population [28].

Dietary Fat and PCOS

The type and amount of dietary fat consumption have implications for weight management, insulin resistance, and cardiovascular risk. By consuming the appropriate qualities and quantities of fat in their diet, women with PCOS can actually help enhance the absorption of healthful fat-soluble vitamins, decrease their overall risk of cardiovascular disease, and even gain reproductive benefit (as the majority of the sex hormones are controlled by dietary fat) [29–31]. Fat also takes far longer to metabolize than dietary CHO, ultimately promoting a sense of fullness and satisfaction.

Fats and oils are made up of basic units called fatty acids. Each type of fat or oil is a mixture of different fatty acids, and independent of the type of fat consumed, all types of dietary serve as equitable sources of energy, yielding 9 calories per gram. An optimal intake for fat for women with PCOS should be between 25% and 30% of total calories consumed. For a woman following a 1500-calorie diet, this would equate to around 40–50 g of fat per day, with an emphasis on food sources containing higher concentrations of monounsaturated and polyunsaturated fatty acids.

Monounsaturated fatty acids (MUFAs) are found mainly in vegetable oils (vegetable, olive, rapeseed, and peanut), nuts and nut butters, seeds, olives, and avocados. Studies support eating a diet rich in MUFAs can improve cholesterol levels, optimize insulin levels, and aid in blood glucose control [32].

Polyunsaturated fatty acids (PUFAs) are found mainly in vegetable oils, almonds, cashews, pecans, avocados, fish, and seafood. Omega-3 and omega-6 fatty acids are types of PUFAs and are considered essential fatty acids because humans are dependent on dietary sources, as these cannot be synthesized in vivo.

Omega-3 fats are particularly relevant for women with PCOS given that a balanced intake of these fatty acids confers anti-inflammatory benefit in a condition that is associated with low-grade systemic inflammation, as evidenced by elevation of multiple clinical markers such as C-reactive protein, interleukin-18, as well as endothelial dysfunction [33]. Adequate omega-3 consumption supports healthy cardiovascular, brain, mood, skin, and immune function as well as decreases cholesterol and triglycerides and improves insulin sensitivity [34–36]. The three major types of omega-3 fatty acids are EPA (eicosapentaenoic acid), DHA (docosahexaenoic acid), and ALA (alpha-linolenic acid). EPA and DHA are found in fatty cold-water fish (like salmon, mackerel, blue fish, albacore tuna, sardines, lake trout, and herring) as well as high-quality supplements (krill, cod liver, and algal oil). ALA is found in seeds, nuts, beans, green leafy vegetables, flaxseed, and canola and soybean oil. In response to the well-demonstrated positive health qualities of omega-3s

and their low occurrence in frequently consumed foods, some manufacturers have started adding omega-3 fatty acids to more commonly consumed foods whose inherent omega-3 values are low. Certain brands of eggs, yogurt, juice, and milks have been fortified with omega-3s in an effort to increase the general population's consumption of these integral fats.

Although *omega-6* fatty acids also play an integral role in health, however, their extreme prevalence in the Western diet – in vegetable oils, animal fats, and bakery goods (donuts, cookies) – is contributory to systemic inflammation. *The optimal ratio of omega-6 to omega-3 in healthy diet is 4:1*, whereas the typical American diet presents with a ratio of 20:1. This imbalance triggers a genetically programmed inflammatory response in the body. Therefore, most women with PCOS could greatly benefit from decreasing their intake of omega-6 fatty acids and increasing their intake of omega-3 fats. Experts recommend a minimum of 200 mg of DHA per day from either fatty fish or fish oil pills [32]. This can also be obtained by consuming at least 12 ounces of fatty fish per week, whereas vegetarians or vegans can take flaxseed oil, a rich source of ALA. Strategies for maximizing dietary intake of omega-3 fatty acids are summarized in Box 3.

Box 3 Tips for Increasing the Omega-3 Content of the Diet

- Add salmon or tuna to a salad with chopped walnuts.
- Select oils that provide omega-3 fatty acids such as canola or walnut oil.
- Sprinkle ground flax, hemp, or chia seeds on your yogurt, cereal, or salad.
- Blend a teaspoon of cod liver oil into your smoothie.
- Spread peanut butter with added omega-3 fatty acids on whole-wheat toast.
- Grill, bake, or broil your favorite seafood with a bit of olive oil (mackerel, salmon, tuna, etc.).

Saturated fatty acids are found mainly in foods from animal sources like high-fat cuts of meat, dairy products made from whole milk (butter, ice cream, cheese, and sour cream), and chicken skin. Some vegetable oils, such as coconut, palm kernel, and palm oil, also contain saturated fat. Saturated fats are reported to raise both total and LDL cholesterol. These foods should be eaten sparingly. National dietary guidelines recommend that saturated fat intake be less than 10% of total calories consumed. For example, if a person consumes 1500 calories per day, she should consume less than 17 g of saturated fat.

Trans-fatty acids are liquid vegetable oils that have been chemically processed to become semisolid at room temperature through the addition of hydrogen atoms. Trans-fatty acids, also called “partially hydrogenated” oils, are used in some margarines, fried foods, cakes, cookies, and processed snack foods to improve the flavor, texture, and shelf life. Surprisingly, many commercial peanut butters also contain trans fats. Trans fats are easily oxidized to form free-radical chain reactions that, in turn, can damage cell membranes and body tissues and compromise immune

function. Research confirms consumption of trans fat may promote inflammation, premature aging, and promotion of various cancers [37–39]. Dietary trans fat content can adversely affect the risk of coronary disease by raising LDL cholesterol levels, lowering HDL cholesterol levels, and raising triglyceride levels [40]. Indeed, in a large, prospective study conducted on more than 800,000 women enrolled in the Nurses' Health Study, researchers found a higher dietary intake of saturated fat and trans fat was associated with an increased risk of coronary disease [40]. By replacing the saturated and trans fat content of the diet with unsaturated fats, there appears to be a clear benefit on blood lipids [41, 42]. Dietary restriction of trans fats should be a priority in women with PCOS who are inherently deemed at an enhanced risk for premature atherosclerosis.

Dietary Calcium

Low-fat dairy-rich foods are excellent sources of protein, calcium, and other important nutrients. Beyond their benefit for skeletal health, adequate dietary calcium is suggested to hold implications for blood pressure lowering and relevant for insulin signaling as well as suggested to have a role in fat metabolism [43, 44]. Table 14.3 presents calcium-rich foods and their relative calcium content. Women with PCOS should aim for 1200–1500 mg of calcium per day, which equates to about three servings per day with dietary sources being preferable to supplementation strategies. Sufficient vitamin D is necessary for the optimal absorption of calcium.

Part-skim mozzarella, farmer's cheese, feta, goat, and low-fat cheeses of all varieties are all excellent low-fat dietary options; these choices are lower in saturated fat and calories than their full-fat counterparts (less than 5 g of fat per ounce).

Vitamin D and PCOS

In contrast to a prevalence of 20–48% among the general adult population, a relative higher prevalence of vitamin D deficiency is observed among women with PCOS (approximately 67–85% of women with PCOS have low levels of vitamin D) [45, 46]. The current research regarding vitamin D levels and PCOS appears inconclusive. Several studies support a higher incidence of lower serum 25(OH)D in women

Table 14.3 Foods rich in calcium

Food	Amount	Calcium content
Milk (1% or nonfat)	8 ounces	300 mg
Yogurt (low-fat)	8 ounces	350–400 mg
Cheese	1 ounce	200 mg
Canned sardines (with bones)	3 ounces	375 mg
Canned salmon (with bones)	3 ounces	170 mg
Leafy greens	1/2 cup	100–150 mg

with PCOS when compared to healthy controls [47, 48], while other studies support no differences in metabolic or endocrine parameters [49–51]. A compromised vitamin D status has been associated with an increased incidence of insulin resistance, metabolic syndrome, type 2 diabetes, and an unfavorable lipid profile [52–54]. In spite of promising studies, inconsistencies in study design, same size populations, as well as differences in the quantity and quality of vitamin D supplementation appear to affect the comparability and ability to reproduce consistent reliable results.

Vitamin D is the only nutrient the body produces when exposed to sunlight. There are two known forms of vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol). Vitamin D3 is only found in animal-sourced foods, whereas D2 mainly comes from plant sources and fortified foods. Both forms can be commonly found in supplements. Due to the fact many individuals avoid exposure to the sun and spend the majority of their time indoors, their ability to generate sufficient vitamin D is compromised. In addition, vitamin D is only found in a select variety of foods including fortified milk and cereals and fatty fish.

The daily value for vitamin D is 800 IU (20 mcg) per day. Table 14.4 presents vitamin D-rich foods and their relative content. The highest sources are found in the fatter fish like wild-caught salmon and halibut with a modest amount in fortified foods like milk, eggs, and orange juice. While the correlation with vitamin D and PCOS still appears unclear, it remains important to encourage women with PCOS to consistently consume adequate vitamin. If they are unable to meet their dietary needs, supplementation should be considered.

There has been a widespread perception that vitamin D2 and vitamin D3 are equally efficacious when it comes to raising vitamin D status [55–57]. Both forms of the vitamin are known to be effectively absorbed into the bloodstream. However, the liver metabolizes each form of the vitamin differently. The liver metabolizes vitamin D2 into 25-hydroxyvitamin D2 and vitamin D3 into 25-hydroxyvitamin D3. Collectively these metabolites are known as calcifediol. Calcifediol is

Table 14.4 Food rich in vitamin D

Food	Amount	Vitamin D content
Cod liver oil	1 teaspoon	448 IU
Wild salmon	3.5 oz.	988 IU
Trout (rainbow)	3.5 oz.	752 IU
Farm-raised salmon	3.5 oz.	526 IU
Tuna (canned), light, packed in oil	3.5 oz.	315 IU
Mushrooms exposed to UV light	3.5 oz.	130–430 IU
Halibut	3.5 oz.	384 IU
Mackerel	3.5 oz.	360 IU
Milk, 2%	8 oz.	120 IU
Milk, skim	8 oz.	120 IU
Soy, almond, or oat milk	8 oz.	100–120 IU
Orange juice	8 oz.	100 IU
Tuna (canned), light, packed in water	3.5 oz.	93 IU
Egg	1 each	40 IU

considered the predominant form of vitamin D. Therefore, its blood levels reflect the active stores of the nutrient.

Over the past two decades, a number of trials have been completed comparing the relative efficacy of vitamin D2 with vitamin D3 in increasing serum total 25-hydroxyvitamin D (25(OH)D). In a 2020 meta-analysis performed by Chakalian et al., researchers examined nine randomized controlled trials that used equivalent dosages of vitamin D2 or D3 in healthy adult participants. The study concluded that both vitamin D2 and vitamin D3 effectively raised vitamin D serum levels. While vitamin D3 led to a slightly higher increase, the difference between the two was not statistically significant [58].

In a 2011 systematic review and meta-analysis performed by Tripkovic et al., researchers found that vitamin D2 supplementation yielded less calcifediol than an equal amount of vitamin D3 [59]. D3 proved to be more effective than vitamin D2 at raising blood levels of calcifediol. This challenges the concept that both forms of the vitamin are equally advantageous relative to supplementation [59, 60]. While the widespread data appears inconclusive, the specific source of vitamin D may be a deciding factor in selecting a supplement. Additional research is needed to determine the specific metabolic pathways involved in hydroxylation as well as the effects across age, sex, and ethnicity. Furthermore, dosing schedules and dosing amounts are all factors requiring more investigation. While both oral vitamin D3 and vitamin D2 have the ability to raise serum concentrations of 25(OH)D, additional studies are needed to determine if supplementation derived from D3 does in fact have a significant positive impact over D2 [61, 62].

Dietary Sodium and PCOS

Given a predisposition to premature atherosclerosis and propensity for endothelial dysfunction, attention to dietary sodium may be relevant for women with PCOS. While sodium occurs naturally in most foods such as milk, beets, and celery, it is a common additive to various food products in forms such as monosodium glutamate, sodium nitrite, sodium saccharin, baking soda (sodium bicarbonate), and sodium benzoate. Sodium is also found in condiments such as ketchup, Worcestershire, teriyaki and soy sauce, onion salt, garlic salt, bouillon cubes, and soup stocks and broths. Processed meats, such as bacon, sausage, and deli meats, and canned soups and vegetables are all examples of foods that contain high amounts of added sodium. Due to their processed nature, fast foods are generally also high in sodium. Sodium intake should be consistent with the dietary guidelines for healthy Americans and be no more than 2300 mg (one teaspoon table salt) per day. Adults with high blood pressure should have no more than 1500 mg per day and are encouraged to choose foods labeled as “reduced-sodium,” “no-salt-added,” or “unsalted” products.

Defining Obesity, Overweight, and Normal Body Weight

It is well documented that obesity and overweight are prevalent characteristics among the PCOS population [63]. While the actual definition of obesity appears to vary, the terms *overweight* and *obesity* imply a weight greater than what is considered healthy. An individual's body mass index (BMI) is often used in defining this criteria.

BMI is calculated by using a person's weight in kilograms (kg) and dividing it by their height in meters (m) squared. An adult who has a BMI of 25–29.9 is considered overweight, while an adult who has a BMI greater than or equal to 30 is obese. A person with a BMI of 18.5–24.9 is considered to be normal weight. A person is morbidly obese (extreme obesity) if his or her BMI is over 40.

Excess weight exacerbates all reproductive and metabolic symptoms of PCOS including clinical and biochemical hyperandrogenism, insulin resistance, glucose intolerance, and an atherogenic lipid profile [64]. The International Evidence-Based Guidelines for the Assessment and Management of PCOS suggest lifestyle modification targeting weight management as the first-line treatment for women with PCOS regardless of presenting symptoms [65]. It has been noted that PCOS symptoms may improve with even a modest weight loss of 5–10% of one's body weight [66]. However, in situations where the individual is morbidly obese, a 25–50% weight loss may be required to experience similar improvements [67].

Caloric Needs and PCOS

An individual's caloric needs are based on a variety of factors including activity level, age, sex, body composition, and their own metabolism. Direct and indirect calorimetry is considered the gold standard for calculating resting energy expenditure (REE) [55]. REE is defined as the amount of calories needed to maintain basic body systems and body temperature at rest. However, due to the expense, time needed to achieve an accurate measurement, and the need for trained personnel to perform this measurement, this method is not commonly used. Therefore, prediction equations are the main clinical method for determining REE.

Currently, there are no validated prediction equations for determining the REE in women with PCOS. However, numerous studies have demonstrated relative accuracy of the Mifflin-St Jeor prediction equation when compared against other equations in calculating REE in obese and overweight people [56, 57]. In a 2018 study conducted by Broskey et al., researchers confirmed that the Mifflin-St Jeor equation was accurate within 10% of the gold standard [58]. In addition, the Academy of Nutrition and Dietetics endorses the Mifflin-St Jeor equation for calculating REE in individuals who are overweight or obese population [59]. Given the high incidence of overweight and obesity in the PCOS population, it would therefore be plausible to apply the Mifflin-St Jeor equation when calculating REE in women with PCOS [60].

The Mifflin-St Jeor equation for calculating REE is as follows:

$$(10 \times \text{weight in kg}) + (6.25 \times \text{height in cm}) - (5 \times \text{age in year}) - 161$$

Therefore, if we applied the Mifflin-St Jeor equation to calculate the REE of a 28-year-old female who is 5 feet 3 inches, weighs 180 pounds, and has a BMI of 32, the calculation would be as follows:

$$(10 \times 81.81 \text{ kg}) + (6.25 \times 160 \text{ cm}) - (5 \times 28 \text{ year in age}) - 161 = 1,662 \text{ calories / day}$$

Once REE is established, next an individual's activity level must be applied to the REE.

- Sedentary = 1.2 (no activity)
- Lightly active = 1.375 (light exercise/sports 1–3 days/week)
- Moderately active = 1.550 (moderate exercise/sports 3–5 days/week)
- Very active = 1.725 (intense exercise/sports 6–7 days/week)
- Extra active = 1.9 (intense exercise + physical job or 2 × per day training 6–7 days/week)

If the individual noted in the example was lightly active, we would therefore:

$$1,662 \text{ calories} \times 1.375 = 2,285.25 \text{ calories}$$

For this woman to maintain her current weight of 180 pounds, she would need to consume around 2285 calories. However, based on her BMI of 32, she is obese and would therefore likely benefit from weight loss. Weight loss can be achieved in theory by deducting 500 calories from her maintenance calories. This is based on the assumption that 1 pound of body fat is equal to about 3500 calories. Therefore, by deducting 500 calories per day for 7 days theoretically should result in a loss of 1 pound of body fat per week.

It is important to appreciate that the Mifflin-St Jeor equation only provides an estimate of calories. More studies in women with PCOS are needed to develop and validate a unique equation for women with PCOS that is reliable given the underlying potential influence of the hyperinsulinemia and hyperandrogenemia prevalent in this population. Many overweight, insulin-resistant women have a challenging time losing weight. They may benefit from seeking the guidance of a registered dietitian to establish a more personalized dietary regime that takes into account their unique metabolic needs and profile.

Behavior Modification in PCOS Management

Snacking and Optimal Meal Patterns

Eating small, frequent meals and snacks not only decreases food cravings and prevents binges, but it also provides a steady flux of energy and helps prevent low blood sugar. Given an inherent tendency towards reactive hypoglycemia and CHO

cravings, women with PCOS are an ideal population to benefit from consumption of small and frequent snacks spaced every 2–4 hours. The optimal meal pattern is to consume breakfast within 1 hour of waking and a snack 2–3 hours later, eat lunch 2 hours later, consume another snack 2–3 hours later, and then eat dinner after another 2 hours. If hungry after dinner, a third snack can be consumed, if needed.

Box 4: Items to be considered as snack substitutes:

Box 4 List of Recommended Snack Substitutes

- 6 ounce plain nonfat Greek yogurt (90 calories)
- 1 small piece fresh fruit with 1/4 cup of low-fat cottage cheese (100 calories)
- 1 small apple sprinkled with cinnamon and 1 tablespoon sugar-free syrup, baked (80 calories)
- 2 graham crackers squares with 1 teaspoon peanut butter (90 calories)
- 12 almonds or 20 peanuts (83 calories)
- 1/2 cup whole-grain cereal and 1/2 cup low-fat milk (100 calories)
- 1/2 cup cooked edamame beans (100 calories)
- 2 tablespoons hummus with 12 grape tomatoes, 2 stalks celery (71 calories)
- 6 medium shrimp with cocktail sauce (60 calories)
- 1 hard-boiled egg (75 calories)
- 1 part-skim mozzarella string-cheese stick (70 calories)
- 1 medium tomato stuffed with 1/3 cup reduced-fat cottage cheese (100 calories)

The guidelines for snacks allow for flexibility. A snack should roughly be around 60–100 calories, 0–20 g of CHO, 0–7 g of fat, and a modest amount of protein (2–8 g), if possible.

Importance of Exercise for PCOS Management

Regular exercise has long been accepted as an effective part of weight management and overall maintenance of physical and mental health. Physical activity can reduce insulin levels, improve insulin sensitivity, and optimize lipid profile as well as may also improve self-esteem, decrease depression, and reduce anxiety in women with PCOS. Therefore, exercise can play an integral role in managing the symptoms of PCOS.

It is well known exercise improves glucose homeostasis associated with insulin resistance [60]. Exercise improves glucose homeostasis by promoting an upregulation of the expression and/or activity of proteins involved in insulin signal transduction in the skeletal muscle [60]. Numerous studies have examined the impact of exercise specific to women with PCOS. In a study performed by Vigorito et al., 90 young women with PCOS were randomly subdivided into two groups, each composed of 45

subjects. The PCOS-T (trained) group underwent a 3-month structured exercise training program, whereas the PCOS-UnT (untrained) group maintained an unaltered lifestyle. This study demonstrated that a 3-month structured exercise training program induced a significant improvement in cardiopulmonary functional capacity and insulin sensitivity and also led to a significant reduction in BMI and CRP levels in a wide overweight PCOS population [61]. In yet another study by Brown et al., researchers demonstrated that moderate-intensity exercise without significant weight loss improved several components of the lipoprotein profiles of women with PCOS. There were significant reductions in the concentration of large VLDL/chylomicrons and medium/small HDL, and increased large HDL and average HDL size in the exercise group compared to controls. Further, there were reductions in calculated triglycerides and VLDL triglycerides in the exercise group compared to controls [62]. These findings support the recommendation to increase physical activity in women with PCOS to obtain improvements in the overall metabolic picture and to reduce the overall risk for cardiovascular morbidity in this population.

However, in spite of the ongoing research supporting evidence-based exercise recommendations aimed at women with PCOS, a finite modality has not been established. Without conclusive population-specific results, the recommendations for exercise and physical activity, therefore, must be applied from the general population data. More data from exercise intervention literature needs to be evaluated to garner a better understanding of the specific health impact of various forms of exercise in women with PCOS. Overall, a stronger body of evidence is required to better assess what exercise modalities and in what combinations are necessary to achieve optimal health outcomes in women with PCOS.

Putting It All Together

Sample Menu Plans for PCOS

1200- to 1400-Calorie Sample Menu

Breakfast

- 1 1/4 cup of strawberries
- 1 container (5.1 oz.) plain nonfat Greek yogurt
- 1/2 cup high-fiber cereal
- 6 walnuts

Lunch

- 4 ounces of grilled chicken
- 2 cups of Romaine lettuce with 1 cup of assorted non-starchy vegetables
- 1 tablespoon of olive oil
- 1 tablespoon of balsamic vinegar

- 1 small orange

Dinner

- 4 ounces of grilled salmon
- 1 cup of green beans with 2 teaspoons butter
- 1 cup of cooked wild rice
- 8 oz. 1% milk

Snacks

- 1 ounce of low-fat cheese (<3 g of fat)
- 1 whole-grain granola bar

Totals 1440 calories, 120 g of carbohydrates (33% total calories), 25 g of fiber (100% of needs), 52 g of fat (33% of total calories), and 122 g of protein (34% of total calories)

Exercise Recommendations

Currently, there are no PCOS specific exercise guidelines. The Physical Activity Guidelines for Americans supports the recommendations for physical activity should be no less than 150 minutes total per week of moderate-intensity exercise. Activities such as brisk walking, water aerobics, ballroom and line dancing, general gardening, tennis (doubles), or sports in which one catches and throws (baseball, softball, volleyball) are all considered to reflect moderately intense physical activity. When exercising moderately, an individual should be able to talk but not sing. If the individual chooses to increase the intensity of exercise (while decreasing the duration), recommendations are for 75 minutes total per week. Vigorous-intensity activities include race walking, aerobic dance, biking faster than 10 miles an hour, hiking uphill, heavy gardening, jumping rope, martial arts (such as karate), jogging, running, swimming fast laps, tennis (singles), and any sport that involves a significant amount of running (basketball, soccer, field hockey). During vigorous activity, an individual should not be able to say more than a few words before breathing deeply. Activities that strengthen the muscles, improve balance, and preserve bone, such as weight training, using resistance bands, weight-bearing aerobics, and heavy gardening, are recommended to be included 2 or more days per week.

In spite of the numerous benefits of exercise for women with PCOS, getting started can be challenging. Therefore, starting with low-impact exercise like walking and swimming is encouraged. While 150 minutes of moderate exercise per week is the goal, movement of kind and duration should be encouraged and supported in this population.

Summary

The majority of women with PCOS are overweight and therefore likely to benefit from weight reduction strategies. Successful weight loss can be achieved through a combination of dietary modifications and restrictions. Minimizing intake of simple CHO, saturated fats, and omega-6 fatty acids, optimizing dietary fiber and omega-3 fatty acid content, ensuring against spells of starvation, and encouraging intake of frequent and small meals are strategies that will facilitate improvements in metabolic as well as phenotypic burden of PCOS. Regular physical activity of moderate intensity in conjunction with the specified dietary modification is sure to further enhance the overall health benefit.

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