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REVIEW

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Impact of dietary fiber on PCOS: a systematic review

Cassandra M. Swanson[1], Yates Barker[1] and Ryan Patterson[1*]

Abstract

Background Studies have shown that altering dietary fiber intake may help alleviate symptoms and improve health outcomes for polycystic ovary syndrome (PCOS) in women. This systematic review intends to assess dietary fiber intake amongst PCOS individuals and assess if modifying fiber is a useful and positive intervention for otherwise healthy obese and non-obese PCOS patients.

Methods PubMed was searched in correlation with the use of a specific search strategy, screening process, and PRISMA checklist to locate available RCT and observational studies.

Results The studies provided are reasonably consistent in observing weight loss and aspects of positive metabolic outcomes. Anthropometrics include reductions in body mass index (BMI), waist circumference (WC), and total body fat. Glucose regulation is indicated through reductions of fasting blood sugar (FBS), fasting insulin, and homeostatic model assessment of insulin resistance (HOMA-IR). Improving insulin sensitivity through increasing fiber intake may impact luteinizing hormone (LH) and follicular stimulating hormone (FSH) levels. Regarding hormones, these studies suggest a relationship between elevated LH levels amongst PCOS individuals at baseline. Although many studies did not measure LH and FSH, a modest reduction in LH levels and a minimal reduction of FSH after a dietary intervention involving increased fiber was observed. The underlying mechanism may include increasing fiber intake to improve glucose homeostasis and subsequent insulin resistance (IR) and sensitivity.

Conclusion Overall findings conclude that improved fiber intake is associated with positive effects on metabolic and anthropometric outcomes in PCOS women. Hormonal impacts regarding dietary fiber remain unclear. However, the mechanism between decreased IR by increased fiber intake is not yet apparent. The inconclusive findings regarding these aspects may be due in part to insufficient existing literature. Therefore, while there is growing evidence to support the role of fiber in managing PCOS symptoms, additional research is needed to establish its relationship in improving both metabolic and reproductive outcomes in this population.

Keywords Women, Health, Fiber, PCOS, Menstrual, Ovulation

Background

Polycystic Ovary Syndrome (PCOS) is a common heterogeneous endocrine-metabolic disorder affecting approximately 21% of women of reproductive age worldwide [1]. A recent report showed that an estimated 5 to 6 million women in the United States were affected by PCOS [2]. Despite the high incidence of PCOS, underdiagnosis remains a significant issue, with reports indicating that only 50% of individuals meeting the diagnostic criteria receive a diagnosis within their lifetime [3]. Several literature reviews suggest that genetic factors, gut health, environmental influences, and lifestyle or dietary habits may contribute to its development and progression, although the etiology of PCOS remains unknown [4–8]. Obesity, specifically the central abdominal phenotype [9], is linked as a contributing factor in PCOS development [10]. Additionally, PCOS women are often at risk for

*Correspondence:
Ryan Patterson
Ryanpatterson0402@gmail.com
[1] Texas State University: School of Family & Consumer Sciences, 601 University Drive, San Marcos, TX 78666, USA

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other metabolic disorders such as insulin resistance (IR), impaired glucose tolerance, type 2 diabetes (T2D), metabolic syndrome, dyslipidemia, and obesity [11]. Despite roughly 80% of women affected by PCOS being within the overweight and obesity classification [12], one study demonstrated central obesity was found in 95% [10] of all individuals with irregular menstruation (IM), hyperandrogenism (HA), and polycystic ovaries (PO) in a cohort study. In clinical health settings, the Rotterdam Criteria defines PCOS as the presence of any two of the following: oligo-ovulation and anovulation, HA (biochemical or clinical), and/or polycystic ovarian (PCO) morphology on ultrasound after excluding other endocrinopathies [13]. In line with the Rotterdam criteria, the notable symptoms of PCOS include HA, reproductive abnormalities, and metabolic consequences, specifically IR and hyperinsulinemia (HI).

Reproductive hormone imbalances are a hallmark of PCOS, with 93% of patients presenting with IM, and HA [10]. Additionally, luteinizing hormone (LH), follicle stimulating hormone (FSH), and LH:FSH ratio were also noted to be higher amongst PCOS individuals, specifically those with IM, HA, and PCO characteristics [10]. Both LH and insulin contribute to the production of androgens and have also been proposed as a principal aspect related to weight and anovulation that stimulates ovarian androgenesis in PCOS women [10]. Metabolic abnormalities of glucose homeostasis and improper insulin regulation are another hallmark feature of PCOS and it has been reported that 31.1% of PCOS individuals have impaired glucose regulation [14]. Additionally, PCOS and homeostatic model assessment of insulin resistance (HOMA-IR) are directly correlated with PCOS in multivariate, even when adjusted for body mass index (BMI) [15] which are features that can commonly lead to T2D [16]. This emphasizes the necessity for early and continuous glucose and insulin testing in PCOS women given the suggested predisposition to metabolic abnormalities. Furthermore, literature reviews indicate that women with PCOS are at an increased risk of developing endometrial, breast, and ovarian cancers, highlighting these as important emerging concerns regarding the syndrome's impact on women's long-term health [17].

Despite the health benefits of dietary fiber, only 5% of the American population is reaching their necessary fiber requirements [18]. For women, the current daily recommended intake (DRI) for fiber is 25 g/day [19]. Fiber is associated with improved cardiovascular health, gut motility, decreasing weight and abdominal adiposity, and [20] regulating insulin sensitivity [18]. Fibers may also be fermented in the large intestine to form short-chain fatty acids (SCFAs) that aid to improve metabolic health [21] and blood sugar levels may be altered by slowing the rapid absorption of glucose, improving insulin sensitivity, and decreasing the risk of T2D. Fiber also has proven impacts on anthropometrics, glucose metabolism, insulin regulation, and hormone function, making it a point of interest in its relationship with PCOS [22, 23]. Moreover, finding or maintaining a healthy weight may also be achieved through fiber consumption because it increases satiety while being low in calories [24]. Regarding anthropometric measurements, fiber has been seen in the literature to be an important factor when wanting to decrease anthropometrics such as BMI [25], waist circumference [26], body fat mass, and can aid in weight loss [27]. This may be due to the ability of fiber to promote satiety and its effect on glucose metabolism. The viscidness of fiber slows glucose interaction with enzymes and in turn slows the breakdown, digestion, and absorption. This increases glycemic control and reduces fasting blood sugar (FBS), HOMA-IR insulin, and hemoglobin A1c (HbA1c) levels [28–30]. When observing the reproductive hormone data, fiber has been found in the literature to impact estradiol, and in turn, decreasing LH [31] and can inversely impact concentrations of progesterone and FSH, creating a higher probability of anovulation [31]. Due to these impacts, it has been found in previous literature that low-fiber diets have been associated with higher risk of PCOS development [32, 33]. Positive correlations between physical activity and an altered diet, with a fiber component, on PCOS individuals has been found in some reviews [22, 23]. Although, they remain focused on obesity as a major component, and they do not consider the impact of any one dietary aspect alone. It is also important to keep in mind that there is not an extensive history in research regarding PCOS and lifestyle approaches. With this in mind, we wanted to focus our review specifically on fiber and its previously mentioned impacts. Thus far, clinical literature from observational studies and RCTs has found no statistically significant difference between forms of fiber [34]. Most do not distinguish between fiber types or track changes in intake, indicating that relevant data should be supplemented or these impacts further explored [34].

Due to the lack of comprehensive research, there is currently no single standardized treatment for PCOS, despite its harmful impact on women's health and quality of life. Prescriptions usually entail various contraceptives, antiandrogens, insulin sensitizers, and aromatase inhibitors that may be used off-label in a symptom-oriented manner [35]. Unfortunately, some research has reported certain drugs may cause serious long-term complications in some women, leading researchers to redirect into a diet-based approach [36].

Although other systematic reviews and meta-analyses have explored the intersection of broad dietary intervention and PCOS, to our understanding, our review is unique by focusing on fiber in combining both observational and randomized control trial (RCT) data to assess anthropometric, metabolic, and reproductive outcomes, offering potential mechanisms for future research and emphasizing the notable gap in studies assessing the influence of fiber on reproductive hormones. While dietary fiber may play a role in managing IR and improving metabolic health, its specific impact on women with PCOS, including anthropometric, metabolic, and reproductive outcomes, remains not fully understood. This review systematically evaluates the existing evidence to determine whether increasing dietary fiber intake can positively influence PCOS symptoms and outcomes. By focusing on observational and interventional studies, it examines the association between dietary fiber intake and anthropometric, metabolic, and reproductive hormone parameters. The findings aim to inform dietary fiber recommendations and interventions, with the intention of improving clinical symptoms for PCOS patients. Furthermore, this review emphasizes the need for further research to clarify the impact of dietary fiber related to mitigating PCOS symptoms, which could form the basis for evidence-based dietary guidelines for managing and treating PCOS.

Methods

We developed the search strategy on PubMed for literature up to September 2024 and followed a PRISMA checklist. The search terms used were ("Dietary Fiber"[MeSH Terms] OR "dietary fiber"[Title/Abstract] OR "dietary"[Title/Abstract] OR"fiber"[Title/Abstract] OR "fibre"[Title/Abstract]) AND ("Polycystic Ovary Syndrome"[MeSH Terms] OR "PCOS"[Title/Abstract] OR "Polycystic Ovary Syndrome"[Title/Abstract]) OR "polycystic ovary syndrome"[title] OR ("polycystic ovary syndrome" OR "polycystic ovar*" OR "PCOS" OR "Stein-Leventhal syndrome") AND ("dietary fiber" OR "dietary"[title/abstract] OR "dietary carbohydrate" OR "dietary intake" OR "fiber*" OR "fibre*" OR "dietary") with removing all filters. This search had 898 results which were collectively reviewed by all three authors and narrowed to 9. The study selection and screening process are detailed in Fig. 1.

Inclusion criteria

Eligible references were included in this review if they specifically investigate the effect of dietary fiber intake in the PCOS population and collected information related to anthropometric, metabolic, and reproductive hormone parameters. The inclusion criteria required that RCTs include a fiber-specific intervention, or a diet known to be high in fiber for PCOS women. Additionally, observational studies assessed and measured dietary fiber alongside the previously mentioned assessment parameters amongst the PCOS population. The included anthropometric, metabolic, and reproductive hormone measurements relate to clinical markers commonly seen in PCOS women.

Exclusion criteria

References were excluded in this review that did not measure any dietary fiber intake (daily, soluble or insoluble) were focused on the participants losing weight; did not use the Rotterdam criteria for PCOS; studies that included participants that were in adolescence (under the age of 18); focused on the Mediterranean or Ketogenic diets; had results where the amount of fiber was inconclusive; if the study ranked the participants based on atherosclerosis risk, and all studies that were prior to 2016 were also eliminated to reflect more recent scientific literature.

Research questions

This review evaluates available observational and interventional studies examining dietary fiber intake in women with PCOS during their reproductive years, assessing the impact of dietary fiber intake on PCOS women to answer the following research questions: (1) What are the outcomes of non-intervention dietary fiber intake on specific anthropometric measures (weight, BMI, WC, and total body fat mass), glucose metabolism (FBS, fasting insulin, and HOMA-IR), and reproductive hormone profiles (LH and FSH) in women with PCOS compared to non-PCOS women? (2) What is the effect of dietary fiber interventions on specific anthropometric measures (weight, BMI, WC, and total body fat mass), glucose metabolism (FBS, fasting insulin, and HOMA-IR), and reproductive hormone profiles (LH and FSH) in women with PCOS?

Results

The search yielded 898 results, of which 301 were excluded because of publication year, 201 were excluded based off title, 286 were excluded based off title, 77 were excluded based off abstract, 32 full-text publications were retrieved and obtained for review, of which 23 were excluded and 9 were retained for this literature review. Supplementary Tables 2–4 include additional data collected from the included studies, providing further details on study characteristics, intervention components, and measured outcomes.

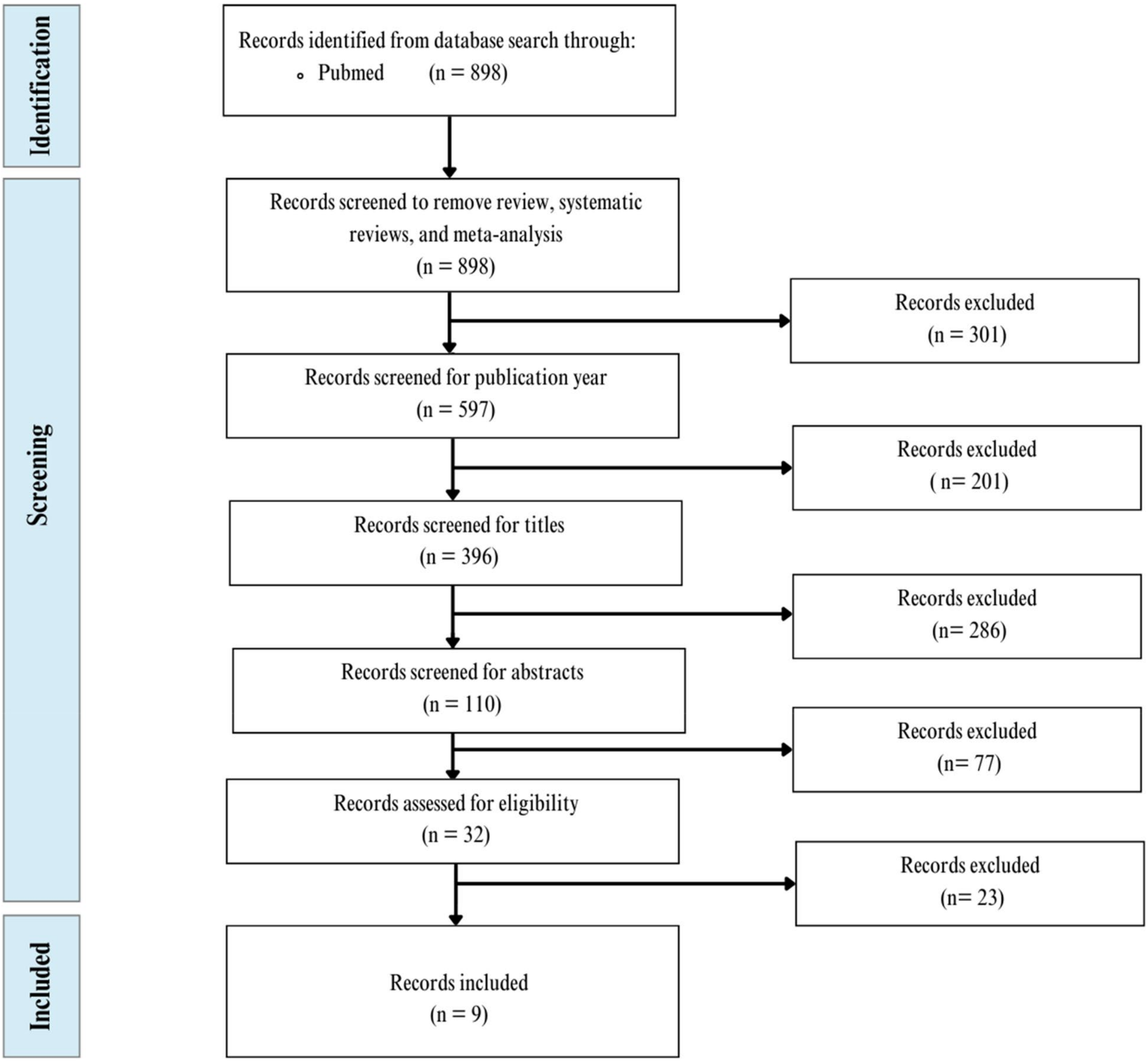

Fig. 1 Flow diagram of literature search. Through a comprehensive search, a total of 898 articles were identified. After the screening process, 32 articles were assessed for eligibility. Of these, 23 were excluded, and 9 articles were ultimately considered eligible and included in the analysis. The included studies comprised 3 randomized controlled trials (RCTs), 5 cross-sectional studies, and 1 case–control study. A flow chart detailing the literature search and selection process is presented in Fig. 1

As shown in Table 1, the studies included in the analysis were published between 2017 and 2022 [11, 12, 34, 37–42]. Across all studies, there were a total of 1479 participants, with 731 participants diagnosed with PCOS and 685 non-PCOS participants [11, 12, 34, 37–42]. The included references are from various countries, providing global representation and retention rates were reported equally amongst RCT and observational studies [11, 12, 34, 37–42]. Six of the included studies were observational studies [11, 12, 34, 37–39]. Included observational studies recorded participant information on mean dietary fiber intake, total energy intake, and BMI [11, 12, 34, 37–39]. None of the six included observational studies differentiated dietary fiber intake into insoluble or soluble categories [11, 12, 34, 37–39]. All observational studies reported that women with PCOS had a dietary fiber intake below the recommended 25 g/day [11, 12, 34, 37–39]. Four studies recorded a high BMI ($\geq$25 kg/m^2) in PCOS participants who consumed less than 25 g/day of fiber, including [11, 34, 37–39]. Of the four studies to report WC, 395 PCOS participants were observed to have a high WC ($\geq$80 cm) and consumed less than 25 g/

day of fiber [11, 34, 38, 39]. Across the studies with PCOS participants consuming less than 25 g/day of fiber, total energy intake ranged from 1487 kcal/day to 3,215 kcal/day, totaling an average of 2292.94 kcal/day [11, 34, 37, 38]. Three studies recorded FBS levels [11, 34, 37] and two reported high FBS (≥ 100 mg/dL) or (> 5.6 mmol/L) in PCOS participants consuming less than 25 g/day of fiber intake [11, 34]. Two studies recorded fasting insulin levels and only one of those studies reported high fasting insulin levels (≥ 15 IU/mL) in PCOS women consuming than 25 g/day of fiber [34, 37]. Three studies reported LH:FSH ratios for women with PCOS consuming less than 25 g/day of fiber [11, 34, 37, 38]. The remaining three studies were RCTs, all of which implemented a specific fiber intervention or an overall diet intervention [40–42]. Only one study consistently reported on dietary fiber intake and total energy intake from baseline to end of study duration finding increased overall fiber intake [40]. All RCTs collected and reported clinical metabolic markers such as anthropometric and glucose homeostasis levels [40–42]. One study reported decreased BMI, WC, and total body fat percentage from baseline to end of study duration [40]. Two studies demonstrated a decrease in total energy intake [40, 41]. Two studies demonstrated a decrease in FBS and fasting insulin levels [41, 42]. Two RCTs demonstrated a decrease in HOMA-IR index [40, 41]. Only one study collected and reported reproductive hormone markers indicating a slight reduction in LH and FSH levels [42] with LH and FSH levels not reported in the remaining two studies [40, 41].

All included RCT studies reported reductions in weight and WC among PCOS participants [40–42]. Two RCT studies reported on total body fat mass demonstrated reductions in total body fat mass among PCOS participants at end of intervention [41, 42]. Two RCT studies reported on FBS demonstrated reductions in FBS levels among PCOS participants at end of intervention [41, 42]. All RCT studies that reported on fasting insulin demonstrated reductions in fasting insulin levels among PCOS participants at end of intervention [41, 42]. All included RCT studies that reported on HOMA-IR showed that increased fiber intake among women with PCOS led to reductions in HOMA-IR at end of intervention [40–42].

Baseline fiber intake and total energy amongst participants was not consistently reported amongst all RCTs. Baseline dietary habits may affect how responsive participants are to dietary changes, with participants starting with lower fiber intake potentially experiencing more pronounced effects from the intervention. Additionally, one RCT included a caloric reduction as a condition for participants. In Nybacka et al., PCOS participants were assigned to one of three intervention groups for four months: a diet-only group, an exercise-only group, or a combined diet and exercise group [40]. The dietary intervention reduced caloric intake while ensuring the consumption of macronutrients and micronutrients aligned with the Swedish Nutritional Recommendations, which are designed to promote optimal nutritional intake for health and disease prevention [40]. The diet-only group increased fiber intake by ~ 4 g/day (from ~ 21 g/day to ~ 25 g/day) and reduced total energy intake by ~ 450 kcal/day (from ~ 2200 kcal/day to ~ 1750 kcal/day) which led to improvements in BMI, WC, and total body fat percentage [40]. The exercise-only group saw smaller changes, with reductions in BMI, WC, and total body fat percentage and the most substantial changes were observed in the diet and exercise combination group, with decreases in BMI and WC, while total body fat percentage remained stable [40]. PCOS participants in the diet-only group reduced HOMA-IR, while the exercise-only group experienced no significant changes over the four-month period [40].

None of the included RCTs reported insoluble versus soluble dietary fiber intake at the baseline or at completion of the study [43–45]. In Afandak et al., PCOS participants were divided into two groups: sumac powder intervention or placebo [42]. The sumac powder group consumed 3 g of sumac (*Rhus coriaria L.*) powder in capsule form daily, though there was no direct record of fiber intake changes in this study only baseline measures were reported [42]. PCOS participants who consumed 3 g of sumac powder daily over the twelve-week period showed only modest improvements in metabolic outcomes [42]. The sumac powder group experienced a reduction in FBS, along with a slight decrease in fasting insulin levels, while the HOMA-IR index remained stable [42]. In contrast, the placebo group had a smaller change in FBS and showed a similar reduction in fasting insulin levels [42]. The HOMA-IR index remained unchanged in both groups [42]. Both groups exhibited comparable changes in fasting insulin and HOMA-IR, with the sumac powder group demonstrating a slightly more notable reduction in FBS compared to the placebo group [42]. In Haidari et al., PCOS participants were divided into two groups: flaxseed intervention + lifestyle modification (LM) or LM only group [41]. The flaxseed group received a 30 g milled flaxseed supplement, providing 8.4 g of dietary fiber per day based on independent testing [41]. From baseline to the end of the intervention, there was no detailed record provided for the change in dietary fiber intake, but energy intake showed a slight decrease in the fiber intervention group, moving from 1935.27 kcal/day to 1868.52 kcal/day [41]. PCOS participants consuming 30 g flaxseed per day showed significant metabolic improvements

Table 1 Summary of included studies related to fiber intake amongst PCOS women: Country, Study design, Study duration, Sample size, Age, Retention, RD counseling session component, Physical activity component, Drug intervention component (Drug used), Dietary assessment method

Reference (author, year)	Country	Study design	Study duration	Sample size	Age (year)	Retention	RD counseling session component	Physical activity component	Drug intervention component	Dietary assessment method
Cunha et al (2019) [34]	Brazil	Observational Case–Control	20 m	$n=73$	18–35	3 completed	No	No	No	7-Day Food Journal
Cutler et al (2019) [37]	Canada	Observational Case–Control	31 m	$n=137$	20–44	137 completed	No	Yes	No	3 Non-Consecutive Day Food Journal
Eslamian et al (2017) [38]	Iran	Observational Case–Control	26 m	$n=779$	20–35	761 completed	Yes	Yes	No	FFQ Recalling 1 Year of Dietary Intake
Liang Z et al (2021) [11]	China	Observational Case–Control	4 m	$n=40$	18–40	40 completed	No	No	No	3-Day Dietary Recall
Lin AW et al (2019) [12]	United States	Cross Sectional Case–Control	66 m	$n=127$	18–45	124 completed	No	Yes	No	FFQ over 3 months
Melekoglu et al. (2020) [39]	Turkey	Observational Case–Control	12 m	$n=130$	19–45	130 completed	Yes	Yes	No	3-Day dietary recall
Nybacka et al (2017) [40]	Sweden	Three Parallel RCT	4 m	$n=57$	18–40	43 completed	Yes	Yes	No	Self-Reported Food Intake
Haidari et al. (2020) [41]	Iran	Two Parallel Open Label RCT	12 w	$n=48$	18–45	41 completed	No	Yes	No	3-Day Dietary Recalls
Afandak et al (2022) [42]	Iran	Double-Blind RCT	12 w	$n=88$	20–40	75 completed	No	Yes	No	24-Hour Dietary Recalls

Abbreviations: MET Metformin, *m* months, *RCT* Randomized Controlled Trial, *RD* Registered Dietitian, *w* weeks such as a decrease in FBS, fasting insulin levels, and an improvement in the HOMA-IR index [41]. In comparison, the LM only group, showed minimal changes in FBS with an increase in fasting insulin and HOMA-IR [41]. Overall, the flaxseed supplement group demonstrated a more significant reduction in FBS, fasting insulin, and HOMA-IR compared to the control group, indicating the flaxseed intervention was more effective at improving metabolic markers in participants with PCOS [41].

Two RCTs included exercise as an additional intervention at varying intensities [40, 41] and only one study provided nutrition support through a registered dietitian (RD) [40]. In Nybacka et al., exercise was included as part of the intervention in some groups, either alone or combined with dietary modifications, through the support of a physiotherapist [40]. PCOS participants in the diet groups also received personalized support and guidance from a RD tailored to their specific needs [40]. PCOS women receiving RD support experienced the greatest decrease in HOMA-IR, showing a more significant improvement when both interventions were combined [40]. In Haidari et al., participants were asked to participate in ~ 30-min workout of moderate exercise, 3 times a week without any additional support or coaching [41]. None of the PCOS participants included in this study had access to personalized nutrition support through a RD [41].

Lastly, only one RCT specifically examined reproductive hormones, such as LH and FSH, which are central to PCOS-related symptoms [42]. In Afandak et al., the PCOS group receiving sumac powder saw a slight reduction in LH levels, with a decrease from 7.1 ± 41.16 at baseline to 6.1 ± 82.16 by the end of the intervention [42]. Similarly, FSH levels decreased marginally from 5.83 to 5.49 over the same period [42]. The placebo group starting at a baseline fiber intake of 20.59 g/day showed no significant changes in LH levels, maintaining a value of 7.1 ± 79.07 and finishing with 7.1 ± 29.14 [42]. FSH levels, on the other hand, increased slightly from 5.16 to 5.89 [42]. Although dietary fiber intake was not directly tracked in this study, the slight reductions in LH levels in the sumac group may suggest a potential hormonal response influenced by the dietary intervention [42].

For all included literature, the Newcastle–Ottawa Quality Assessment Scale was used to evaluate included case control studies for quality and risk of bias. For included randomized control trials, the American Dietetic Association's Quality Criteria Checklist was used to assess the quality and risk of bias in the studies. All studies used in this review were evaluated to be clear of bias and found to be of quality, based on the assessment and scale stated above.

Discussion

Based on the observational studies included in this review, women with PCOS were reported to consume less fiber, with average intakes ranging from 9 to 20 g/day, which falls below the recommended 25 g/day [11, 12, 34, 37–39]. While improvements in various metabolic and anthropometric markers were predominately reported in RCTs through the use of dietary intervention, it is not conclusive enough to say adequate or improved fiber intake in PCOS women can fully reverse or prevent symptoms.

Association of low dietary fiber intake on health outcomes in women with PCOS

Across the observational studies, notable differences in weight, BMI, and WC were observed between women with PCOS and non-PCOS women, with poorer outcomes among PCOS women who reported dietary fiber intake below the recommended 25 g/day for women [11, 12, 34, 37–39]. Comparable results have been reported in other studies suggesting improved insulin sensitivity with higher fiber intake [46, 47]. A case–control study compared PCOS patients between the ages of 18–45 years old to non-PCOS women control and reported PCOS women had lower intakes of fiber and significantly higher weight, BMI, and WC [47]. An observational cross-sectional, case–control study examined physical activity and dietary patterns, between young women with PCOS compared to healthy controls [46]. The adolescent PCOS group exhibited significantly higher fasting insulin and HOMA-IR levels, indicating greater IR with an inverse correlation between fiber intake and both fasting insulin and HOMA-IR [46]. Additionally, a high or medium glycemic index diet was positively correlated with higher insulin levels, potentially worsening IR, while fiber intake was negatively correlated with metabolic markers like glucose, insulin, and WC [46].

Impact of fiber intake on anthropometric measurements, metabolic health, and reproductive hormones

Research shows that dietary fiber can slow down glucose absorption, leading to lower blood sugar levels and reduced insulin release after meals which may improve insulin receptor activity and increase insulin sensitivity in women with PCOS [45, 48–63]. As seen through significant improvements in anthropometric, metabolic, and reproductive hormone markers in fiber intervention studies, this likely contributes to better glucose homeostasis [33, 40–42]. Dietary fiber is a non-digestible carbohydrate originating from plant-based foods [20] and is an essential part of the diet [18]. Both soluble and insoluble forms of fiber have been associated with improved cardiovascular and metabolic health [20] as indicated by improved clinically relevant metabolic and anthropometric markers. However, the impact of fiber supplementation on PCOS populations remains underexplored.

As previously mentioned, initial fiber and total energy intake, as well as changes from baseline to the end of the study, were not consistently reported across all RCTs, which may influence interpretation of the results. Results reported by Nybacka et al. suggest that baseline dietary habits, such as initial fiber and calorie intake, along with any caloric reductions, can influence the effectiveness of dietary interventions [40]. Therefore, differences in dietary intake and calorie adjustments should be considered when evaluating changes in metabolic and body composition outcomes in PCOS studies.

While each RCT used a distinct dietary approach, such as increased fiber intake via general diet, flaxseed supplementation, and sumac powder, variations in fiber sources and forms could influence how fiber impacts glucose metabolism, insulin sensitivity, and overall metabolic markers [43–45]. Additionally, not all nutrient supplements were independently tested to provide an accurate composition or classified by their soluble fiber versus insoluble fiber concentrations. The specific composition of each intervention might affect the bioavailability of fiber, potentially leading to different levels of efficacy in metabolic improvements. Consistent with one of the RCTs discussed in this systematic literature review [41], Mirmasoumi et al. demonstrated flaxseed oil omega-3 supplementation in women with PCOS significantly improved insulin metabolism, including reductions in fasting insulin, HOMA-IR, and increases in insulin sensitivity as measured by the QUICKI index [44]. Additionally, the supplementation led to a reduction in the severity of hirsutism [44]. Collectively, these findings suggest that differences in fiber sources and forms, as well as the lack of detailed fiber composition tracking, could partly explain the varied impacts on metabolic markers seen in improving metabolic outcomes in PCOS participants.

The included RCTs also varied in whether they incorporated physical activity or nutrition support provided by a RD. Including physical activity could enhance metabolic and anthropometric outcomes beyond what dietary changes alone achieve, explaining some variation in the above reported results [40]. Including RD support could enhance outcomes beyond what physical changes alone achieve, explaining some variation in the above reported results [41]. The use of an RD in a separate study also demonstrated positive outcomes for PCOS women enrolled in the trial assigned to either a Pulse based or Therapeutic Lifestyle Changes (TLC) diet [43]. Both groups observed reductions in weight, BMI, WC, and total body fat mass [43]. These differences in exercise support and access to personalized nutrition guidance may have contributed to the reported variations in metabolic outcomes. This suggests that structured support, both in physical activity and dietary management, can influence the effectiveness of interventions for PCOS populations.

Assessing reproductive hormones is important for understanding the full impact of dietary interventions on PCOS women. The minimal changes in LH and FSH reported were relatively modest and warrant further investigation to explore any potential links between dietary fiber intake and reproductive hormone modulation in PCOS individuals [42]. Although distinct in design, a separate study also aimed to evaluate the effects on sex hormones and gut microbiota in PCOS women [45]. PCOS women were assigned to either a high-fiber diet or a high-fiber diet combined with acarbose with both groups experiencing positive changes in gut microbiota were linked to clinical parameters related to PCOS such as decreased BMI, IR, HA, and body composition [45]. Furthermore, the high-fiber diet combined with acarbose group showed a steady decrease in the LH/FSH ratio throughout the intervention, indicating an improved hormonal balance [45].

Lastly, background PCOS medications potentially taken by participants during the study duration were not fully accounted for, which could influence both metabolic and reproductive outcomes and result interpretation. Including hormone measurements and accounting for medication use would offer a more comprehensive view of how dietary interventions affect both metabolic and reproductive health in PCOS, providing valuable insights into their potential benefits for hormonal balance in PCOS women.

Culture/race comparison

Included observational studies demonstrated an overarching theme of PCOS women having low dietary fiber intake despite geographical differences. Specifically, in China, the United States, Brazil, Canada, Iran, and Turkey, it was found that fiber intakes were below 25 g/day [11, 12, 34, 37–39]. It was also shown that all the PCOS women from these studies had increased anthropometrics when compared to nonPCOS women. Lastly, reports on metabolic and reproductive factors, such as FBS, fasting insulin, HOMA-IR, and LH ratios, varied in the studies due to each study having a unique objective. However, no changes in these components were seen to be unique to a country or region. It can be assumed that locational differences could play a role in certain subgroups or demographics, although these trends remained apparent throughout the country. PCOS women having low

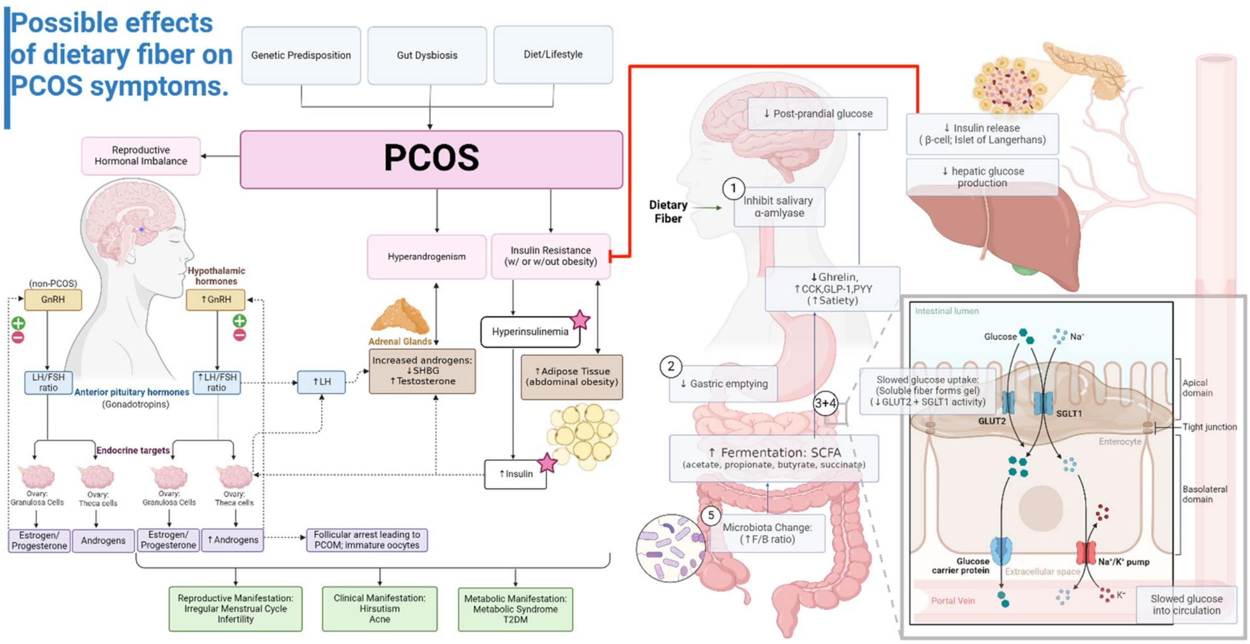

Fig. 2 Possible Mechanism. Biorender image illustrating the possible effects of dietary fiber intake on PCOS. Abbreviations: (CCK) Cholecystokinin; (F/B ratio) Firmicutes to Bacteroidetes ratio; (FSH) Follicle-Stimulating Hormone; (GLUT2) Glucose Transporter Type 2; (GLP-1) Glucagon-Like Peptide-1; (GnRH) Gonadotropin-Releasing Hormone, (LF) Luteinizing Hormone; (PCOS) Polycystic Ovary Syndrome; (PCOM) Polycystic Ovaries Morphology; (PYY) Peptide YY; (SCFA) Short-Chain Fatty Acids; (SHBG) Sex Hormone-Binding Globulin; (SGLT2) Sodium-Glucose Cotransporter-2; (T2DM) Type 2 Diabetes Mellitus [33, 40–42, 45, 48–63]

intakes of fiber could be due in all these countries to the price of fiber rich foods, a knowledge gap, or other barriers to allocation. Dietary habits in respect to culture and region would have to be further studied before being able to accurately carry out an analysis regarding PCOS and fiber.

Included RCTs focused on dietary intervention: one altering only the diet, one having an additional exercise component, and one focused on a fiber supplement [40–42]. After comparing these results, it was seen that all found improvements in anthropometrics and metabolic outcomes of PCOS women. The studies were conducted in Sweden and two different regions of Iran; however, the results seemed to be coinciding, suggesting that regional and cultural differences may not imply the drastic difference we thought it would [43–45].

Possible metabolic pathways

Evidence directly comparing soluble and insoluble fiber in PCOS populations is lacking, however, this systematic review draws on broader metabolic literature to outline potential differences in their physiological effects, which may help explain the variations observed in the included studies. While the root cause of IR in PCOS is largely unknown and the underlying mechanism remains to be elucidated, IR and HI are major features of PCOS contributing to HA and reproductive dysfunction by various mechanisms and may represent one of the most significant developments in understanding the disorder, potentially aiding in improved management strategies [48, 64]. Women with PCOS, whether obese or non-obese, tend to exhibit greater IR and HI [48]. Some research indicates that some women with PCOS exhibit IR characterized by reduced insulin receptor tyrosine kinase activity, and future studies exploring the relationship between this specific IR type and dietary fiber intake in women with PCOS would be valuable [49]. This metabolic abnormality can lead to excess cytochrome P450c 17α-hydroxylase/17,20-lyase (CYP17) in ovarian theca cells [48, 50] and increased testosterone production [50, 64]. Research shows reducing insulin levels with metformin in women with PCOS decreased CYP17 activity, LH levels, and free testosterone levels with increased SHBG [50, 64]. Additional research has established a clear link between insulin and reproductive hormone regulation seen in PCOS, particularly its involvement in ovarian steroidogenesis and gonadotropin release [51, 52]. Addressing these metabolic abnormalities with fiber may be beneficial in managing metabolic and reproductive symptoms of PCOS (Fig. 2).

Dietary fiber may improve insulin regulation in women with PCOS through several mechanisms. One mechanism involves the ability of fiber to inhibit digestive enzymes, slowing carbohydrate breakdown, delaying nutrient absorption [63], and resulting in a more gradual release of glucose into the blood [53]. High-fiber foods also have a lower energy density and require more chewing, which may reduce overall energy intake [53]. A second mechanism involves the role of dietary fiber to slow gastric emptying, as seen with barley [54] and oat β-glucans [55], which delays intestinal transit and promotes satiety [54, 55]. A third mechanism involves the ability of fiber to impair glucose absorption by reducing the expression of sodium-glucose cotransporter-1 (SGLT1) and glucose transporter 2 (GLUT2) [56]. Research has demonstrated oat β-glucan can impair SGLT1 and GLUT2 activity by increasing the viscosity of the surrounding medium, creating a physical barrier near the epithelial cell layer [56]. The final proposed mechanism involves the ability of dietary fiber to modify gut microbiota, promoting beneficial changes that affect metabolic health and hormone regulation [57]. An RCT demonstrated that fiber increased the Firmicutes to Bacteroidetes (F/B) ratio [57]. During fiber fermentation in the gut, the improved F/B ratio increases production of short-chain fatty acids (SCFAs) which influence metabolic pathways and hormone secretion [58]. SCFA can promote glucose uptake in muscle and adipose tissue, increase satiety, and reduce overall food intake by stimulating the release of peptide YY (PYY), glucagon-like peptide-1 (GLP-1), and cholecystokinin (CCK) while reducing the release of ghrelin [54, 57–62] which influence post prandial signaling sent to the brain. In combination, this hormonal response aids in appetite regulation, glucose homeostasis, and insulin regulation further demonstrating the potential of fiber to improve metabolic outcomes in PCOS women [54, 57–62].

Research shows the end result of dietary fiber to slow glucose absorption, reducing postprandial blood glucose levels and insulin release, which may enhance insulin receptor activity and insulin sensitivity in PCOS women [45, 48–63]. The role of fiber to regulate insulin also likely contributes to better glucose homeostasis, as seen through significant improvements in anthropometric, metabolic, and reproductive hormone markers in fiber intervention studies [33, 40–42]. Suggesting that increasing dietary fiber intake can positively influence insulin homeostasis, resulting in improved clinical symptoms of PCOS. Given that observational studies in this review reported women with PCOS typically consume inadequate levels dietary fiber, there is a clear need for further research to address these gaps and investigate the mechanisms by which fiber impacts PCOS health outcomes [11, 12, 34, 37–39].

Implications for practice

Given the findings of this systematic literature review, five key areas are recommended as future directions for research and practice. Firstly, the strong connection between IR and PCOS highlights the need for further research into the effects of dietary fiber on IR and its role in improving PCOS outcomes. A clearer understanding of this mechanism could inform future clinical practice, promoting dietary fiber as a therapeutic strategy for women with PCOS. Secondly, as reproductive hormones such as LH and FSH were not consistently reported, future research could focus on how fiber intake influences these hormones, offering a more comprehensive understanding of dietary interventions in managing reproductive symptoms of PCOS. Thirdly, many RCTs have focused on short-term fiber interventions, leaving a gap in understanding the long-term effects of fiber intake on metabolic and reproductive outcomes in PCOS. Future studies should prioritize long-term interventions to evaluate sustained benefits. Fourthly, while RCTs have shown improvements in PCOS symptoms related to increased fiber intake, combining fiber with other lifestyle changes (such as exercise or medications) could be explored to develop more holistic treatment plans. Lastly, nutrition interventions provided by the Nutrition Care Manual recommend a general healthful diet [65] and two different carbohydrate-modified diets [66, 67]. Based on the National Academy of Medicine, the fiber recommendation for women under the age of 50 is 25 g, while women over 50 years old is 21 g [68]. Clinical practice, however, has established that PCOS women should aim for an intake of dietary fiber between 25 to 29 g, with greater benefits seen with intake over 30 g [68]. As previously mentioned, for women, the current DRI for fiber is 25 g/day [19]. Food sources recommended that are high in fiber are whole grains, beans, legumes, nuts, seeds, fruits, and vegetables [69]. Specifically, implementing diets that emphasize higher dietary fiber consumption, are highlighted as major focal points due to research supporting the ability of fiber to regulate insulin metabolism, slow carbohydrate absorption, and reduce blood glucose spikes commonly seen as symptoms in PCOS [70]. Considering the variability in fiber intake and response between PCOS and non-PCOS women, future clinical practice may benefit from personalized dietary counseling by RDs, tailored to individual metabolic and hormonal profiles investigating specific effects of soluble and insoluble fiber, particularly for symptom mitigation in women with PCOS.

Study strengths and limitations

The strengths of this review include its central focus on fiber reporting and intervention, combined with both observational and RCT data, to assess anthropometric, metabolic, and reproductive outcomes related to the health of women with PCOS. Another strength is its large sample size of a total of 1479 ($\underline{n}=1479$) across the nine included studies [11, 12, 34, 37–39]. There were also a variety of countries in the studies from developed and developing countries including, Brazil, Canada, China, Iran, Sweden, Turkey, and United States [11, 12, 34, 37–39]. All studies had PCOS well defined, consistently followed the Rotterdam criteria, and gathered relevant anthropometric data [11, 12, 34, 37–39]. Only one of the included studies matched women with and without PCOS with respective BMI [38]. Some studies reported that they were the first of their kind; the first study on PCOS in Canadian women that assessed diet with physical activity [37]. The first study to assess type of carbohydrate intake in women with PCOS in a developing country [38]. The first study to evaluate sumac powder supplementation in relation to cardiometabolic factors in women with PCOS [42]. The possible limitations of the included studies include, firstly, that all nine of the studies dietary recall methods could have underreported or over-reported food consumption [11, 12, 34, 37–39]. Six of the studies were observational and therefore non-mechanistic in their findings [11, 12, 34, 37–39]. However, even though they do not point to a direct mechanism, their findings allude to a potential mechanism being present between fiber intake and women with PCOS [11, 12, 34, 37–39]. Secondly, a limitation of some included studies is their acknowledgment of small sample sizes [11, 12, 39, 42]. Lastly, another limitation is that LH:FSH levels were not consistently recorded on specific days of the menstrual cycle [37, 42]. As hormone levels vary widely from one menstrual phase to another, this is an important point to note for future studies.

While other systematic reviews and meta-analyses have reported on the intersection of PCOS and fiber, to our understanding, our review is unique in combining both observational and randomized control trial (RCT) data to assess anthropometric, metabolic, and reproductive outcomes, offering potential mechanisms for future research and emphasizing the notable gap in studies assessing fiber's influence on reproductive hormones. While dietary fiber may play a role in managing IR and improving metabolic health, its specific impact on women with PCOS, including anthropometric, metabolic, and reproductive outcomes, remains not fully understood. This review systematically evaluates the existing evidence to determine whether increasing dietary fiber intake can positively influence PCOS symptoms and outcomes. By focusing on observational and interventional studies, it examines the association between dietary fiber intake and anthropometric, metabolic, and reproductive hormone parameters. The findings aim to inform dietary recommendations and interventions, with the intention of improving clinical symptoms for PCOS patients. Furthermore, this review emphasizes the need for further research to clarify dietary fiber's impact related to mitigating PCOS symptoms, which could form the basis for evidence-based dietary guidelines for managing and treating PCOS.

Conclusion

This paper aims to fill the gap in the literature regarding effects of dietary fiber on specific anthropometrics, glucose metabolism, insulin, regulation, and reproductive hormones in women with PCOS without a weight loss focus. Overall findings conclude that improved fiber intake is associated with positive effects on metabolic and anthropometric outcomes in PCOS women with unknown effects on LH and FSH. Based on this data and clinical practice, women with PCOS could benefit from consuming at least 25 g to 29 g of dietary fiber, which may support positive hormonal impact.

However, many studies did not measure LH and FSH or control for menstrual cycle phase, limiting the interpretations available regarding the effect of fiber on reproductive health in PCOS women. The inconclusive findings regarding these aspects may be due in part to insufficient existing literature. Overall, while this review offers valuable insights, definitive conclusions on dietary fiber's role in PCOS management remain challenging. Therefore, while there is growing evidence to support the role of fiber in managing PCOS symptoms, additional research is needed to establish its relationship in improving both metabolic and reproductive outcomes in this population.

Supplementary Information

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Supplementary Material 1

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Declarations

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