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REVIEW

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# Impact of bariatric surgery on anthropometric, metabolic, and reproductive outcomes in polycystic ovary syndrome: a systematic review and meta-analysis

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## Summary

Polycystic ovary syndrome (PCOS) is a common endocrine disorder in females. Modest weight loss improves reproductive and metabolic PCOS features. While lifestyle modifications and pharmacotherapies remain first-line weight loss strategies, bariatric surgery is emerging as a potentially effective treatment. We performed a systematic review and meta-analysis of published literature to examine the impact of bariatric surgery in PCOS to inform the 2023 International PCOS Evidence-based Guidelines. Electronic databases were searched for observational studies and trials comparing pharmacologic or lifestyle treatments to bariatric surgery in women with PCOS or bariatric surgery in women with or without PCOS. Anthropometric, reproductive, hormonal, and metabolic outcomes were included and, where possible, meta-analyzed using random-effects models. Risk of bias and evidence quality were assessed. Ten

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studies were included involving 432 women with and 590 women without PCOS. Comparisons between bariatric surgery and pharmacologic or lifestyle treatments were only reported in one study each, and most reproductive outcomes were limited to a single study; therefore, meta-analyses could not be performed. Meta-analysis found that women with PCOS experience similar improvements in anthropometric, hormonal, and metabolic outcomes after bariatric surgery compared to those without PCOS. Existing research is limited and of low quality with high risk of bias, especially in comparison to existing PCOS treatments and with respect to reproductive outcomes including pregnancy, highlighting the need for additional studies to inform clinical recommendations.

**KEYWORDS**
bariatric surgery, metabolic surgery, polycystic ovary syndrome, women's health

## 1 | INTRODUCTION

Polycystic ovary syndrome (PCOS) is a common endocrine condition among premenopausal women, characterized by menstrual dysfunction, hyperandrogenism, and polycystic ovaries.[1] Excess weight is a common feature of PCOS from early childhood onward with approximately 61% of individuals with PCOS having overweight or obesity in adulthood, varying by geographic region and ethnicity.[2–4] As with general populations, excess weight worsens reproductive and metabolic health outcomes across the life course in individuals with PCOS.[5]

First-line treatment of PCOS involves adopting healthy lifestyle behaviours to achieve and maintain a healthy weight. As little as 5% weight loss improves PCOS features such as menstrual dysfunction and infertility.[6] Diet and exercise remain the main pillars of weight reduction in PCOS, acknowledging significant challenges to sustainability, and hence, consideration for pharmacotherapy is recommended, according to general population guidelines.[7]

Bariatric surgery is emerging as a potential adjunct therapy for PCOS for patients with excess weight. A systematic review in 2016 found that women with PCOS and clinically severe obesity undergoing bariatric surgery experienced improvements in hirsutism, menstrual regularity, and fertility.[8] The efficacy and safety of bariatric surgery compared to existing strategies for weight reduction in PCOS are not well described. There is also limited evidence regarding outcomes from bariatric surgery in women with PCOS compared to women without PCOS.

Our objective was to perform a systematic review and meta-analysis of the literature to determine the efficacy of bariatric surgery in improving anthropometric, reproductive, hormonal, and metabolic outcomes among women with PCOS. Specifically, we sought to examine outcomes and adverse events from bariatric surgery compared to (1) conservative weight reduction strategies or (2) pharmacologic treatment of PCOS and compare the effects of bariatric surgery in women with and without PCOS.

## 2 | METHODS

### 2.1 | Protocol and registration

This systematic review was conducted to inform the development of the 2023 International Evidence-based Guidelines for the Assessment and Management of PCOS.[9] Results of the systematic review were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,[10] with a protocol registered a priori (PROSPERO CRD42022348585).

### 2.2 | Search strategy and data sources

An electronic search strategy was developed in consultation with an experienced health sciences librarian (CM). Full details of the keywords and Medical Subject Heading (MeSH) terms used are presented in Table S1. The two key concepts outlined in the search were PCOS and bariatric surgery. Bariatric surgery was taken to refer to any surgical procedure performed on the gastrointestinal tract to induce weight loss, including, but not limited to, Roux-en-Y gastric bypass, sleeve gastrectomy, and biliopancreatic diversion. The electronic databases searched included Ovid MEDLINE (R), Ovid EMBASE, Ovid PsycINFO, Ovid All EBM, and CINAHL (inception through November 2022). Searches were limited to English studies in humans. We consulted with experts in the field and hand-searched the reference lists of all included articles to ensure that no eligible studies were missed.

### 2.3 | Study selection

Articles retrieved from each database were compiled and duplicates removed. Two reviewers (JLB, KSC) independently screened titles and abstracts, examined full texts, extracted data, and evaluated study risk

of bias and overall quality of the evidence. Eligible studies were those that met the following criteria: (1) population: women with PCOS diagnosed by Rotterdam[1] or National Institutes of Health (NIH)[11]; (2) intervention: individuals with PCOS who underwent bariatric surgery; (3) comparator: individuals with PCOS who underwent an alternate intervention (i.e., lifestyle management, pharmacotherapy), or individuals without PCOS who underwent bariatric surgery; (4) outcomes: at least one pre-specified outcome reported postoperatively (as outlined in the section below); and (5) study design: observational study (cohort, case–control, or cross-sectional) or a trial (randomized or non-randomized). Only studies published in English and with the full text available were included. Systematic reviews and evidence-based guidelines were excluded; however, reference lists were screened for relevant original research.

At each stage of the review, Cohen's kappa (κ) statistic was used to assess agreement between reviewers regarding the inclusion of articles.[12] All discrepancies between reviewers were resolved by consensus.

## 2.4 | Outcomes

Outcomes of interest were pre-specified in our study protocol, informed by those most important to women with PCOS (derived from the guideline consumer participation process).[9] These included anthropometric outcomes (weight, body mass index [BMI], percent total weight loss [%TWL]), metabolic outcomes (fasting insulin, fasting glucose, hemoglobin A1C [HbA1C], total cholesterol, low-density lipoprotein cholesterol [LDL-C], high-density lipoprotein cholesterol [HDL-C], triglycerides), hormonal outcomes (free testosterone, total testosterone, sex hormone binding globulin [SHBG]), reproductive outcomes (regular menstrual cycles, intermenstrual length, ovulation, anti-Mullerian hormone [AMH], pregnancy rate, live birth rate, pregnancy complications, neonatal outcomes), and adverse events.

## 2.5 | Data extraction

Data extraction was performed using a standardized data collection form developed by the guideline committee. Study characteristics extracted included title, author, year of publication, country where the study was conducted, setting, population, PCOS diagnostic criteria, study design, intervention and control details, sample size and results per group, follow-up duration, and summary of findings. For dichotomous outcomes, we recorded the number of events and total participant number in both the intervention/exposure group and control group. For continuous outcomes, we recorded the mean and standard deviation as well as the sample size in both groups. Factors affecting internal and external validity were also extracted to generate an overall assessment of risk of bias for each study. Data management was performed using Covidence (Veritas Health Information Limited, Melbourne, Australia).

## 2.6 | Risk of bias assessment

Methodological quality was assessed by completing standardized templates developed by the guideline committee. This consisted of a series of questions evaluating internal and external validity based on Cochrane risk of bias assessment tools, followed by an overall assessment of the study's risk of bias. Different templates were used according to study design. Discrepancies between reviewers were resolved by consensus.

## 2.7 | Data analysis

The relative effects of bariatric surgery on health outcomes were assessed in three different comparisons: (1) bariatric surgery versus pharmacotherapy in women with PCOS; (2) bariatric surgery versus lifestyle management in women with PCOS; and (3) bariatric surgery in women with versus without PCOS. The odds ratios (OR) for dichotomous outcomes or weighted mean differences (MD) for continuous outcomes with 95% confidence intervals (95% CI) were calculated to estimate the pooled effects of the intervention. A subgroup analysis was performed to examine the within-group differences pre- and post-bariatric surgery among women with PCOS to address the priorities outlined by consumers in the guideline development process.[9]

Meta-analyses were performed separately for each comparison and study design using random effects models. Statistical heterogeneity was quantified using the $I^2$ statistic, where $I^2 > 50\%$ represents moderate and $I^2 > 75\%$ represents substantial heterogeneity across studies. Publication bias was assessed by visual examination of funnel plots. All statistical analyses were performed using Review Manager Version 5.4.1 (The Cochrane Collaboration, Copenhagen, Denmark).

## 2.8 | GRADE assessments and evidence profile

Quality evaluation was completed for each outcome. This was performed according to the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach.[13] Here, for every comparison, each outcome was evaluated for risk of bias, inconsistency, indirectness, imprecision, and other biases including publication bias and magnitude of effect. Based on these domains, each outcome was assigned an overall GRADE certainty of very low, low, moderate, or high.

# 3 | RESULTS

The PRISMA flowchart summarizing study selection is presented in Figure 1. From 4955 articles retrieved for the title and abstract review, 124 were selected for full-text review. Ultimately 10 studies met criteria for inclusion: eight cohort studies, one cross-sectional study, and one non-randomized trial. There was substantial inter-rater agreement for both the title and abstract review ($\kappa = 0.71$) and full-text review ($\kappa = 0.70$).

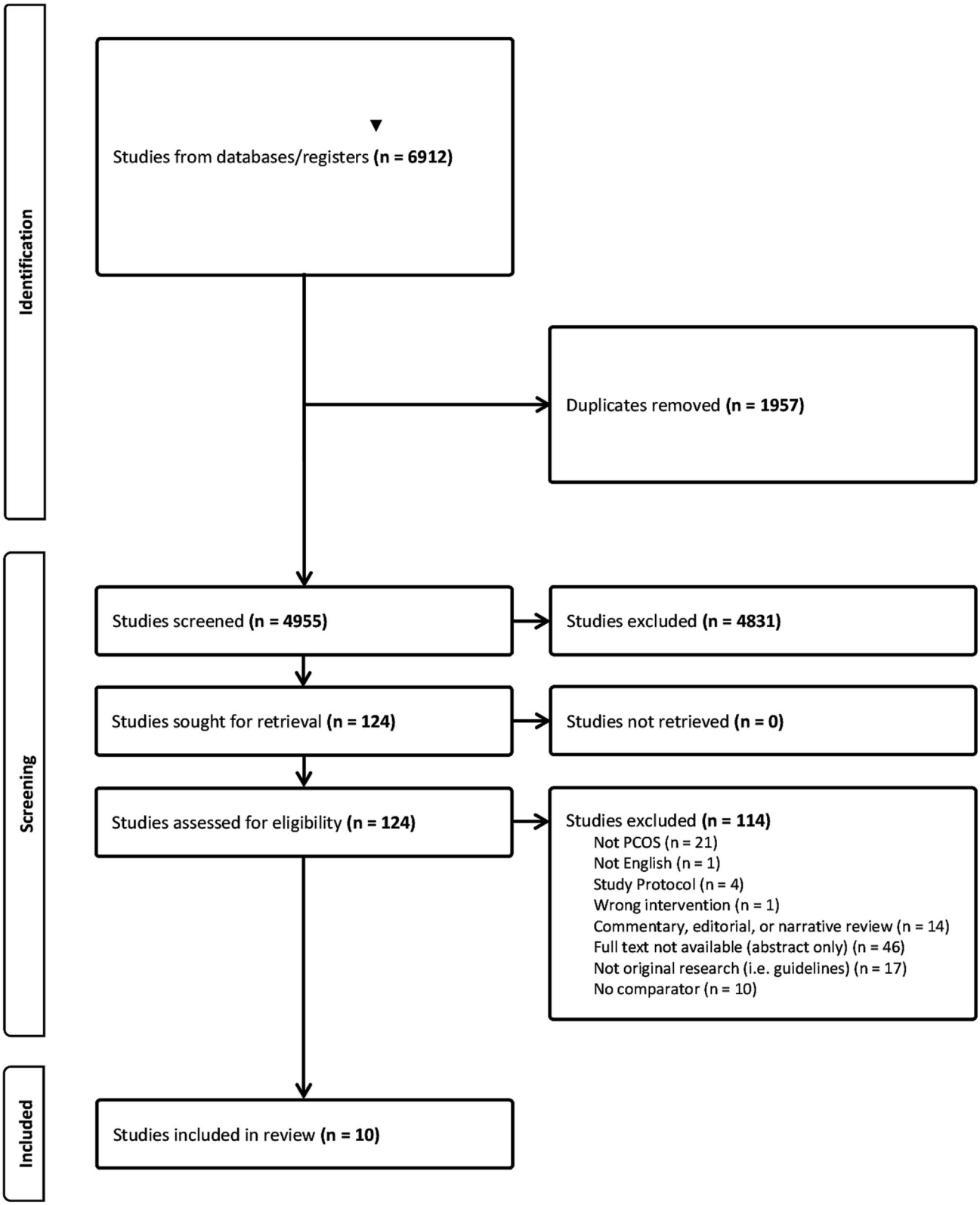


**FIGURE 1** PRISMA flow diagram.

## 3.1 | Study characteristics

Study characteristics are summarized in Table 1. The single non-randomized trial[14] compared bariatric surgery to pharmacotherapy among women with PCOS. Pharmacotherapy consisted of metformin and an oral contraceptive pill containing 35 mcg ethinylestradiol and 2 mg cyproterone acetate. One cohort study[15] compared bariatric surgery with conservative management (lifestyle modification) among

**TABLE 1** Characteristics of all included studies.

| Author | Year | Study design | Country | PCOS diagnostic criteria | Subjects | | Mean age (standard deviation) of subjects with PCOS undergoing bariatric surgery | Type of bariatric surgery | Control | Follow-up duration |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | With PCOS | Without PCOS | | | | |
| Abiad et al[16] | 2018 | Cohort | Lebanon | Rotterdam | 6 | 16 | 24 (5) | Sleeve gastrectomy | Women without PCOS undergoing bariatric surgery | 12 months |
| Ahmed et al[17] | 2022 | Cohort | United Kingdom | Rotterdam | 30 | 60 | 35.5 (standard error 1.3) | Roux-en-Y gastric bypass | Women without PCOS undergoing bariatric surgery | 24 months |
| Benito et al[18] | 2022 | Cohort | Spain | NIH | 49 | 120 | 32.1 (5.3) | Roux-en-Y gastric bypass, sleeve gastrectomy, adjustable gastric banding, revisional surgery | Women without PCOS undergoing bariatric surgery | 24 months |
| Bhandari et al[19] | 2016 | Cohort | India | Rotterdam | 43 | 32 | 27.8 (4.5) | Sleeve gastrectomy | Women without PCOS undergoing bariatric surgery | 6 months |
| Buyukkaba et al[20] | 2021 | Cohort | Turkey | Rotterdam | 23 | 47 | 29.4 (7.1) | Laparoscopic sleeve gastrectomy, Roux-en-Y gastric bypass | Women without PCOS undergoing bariatric surgery | 6 months |
| Cai et al[21] | 2021 | Cohort | China | Rotterdam | 83 | 70 | 29.0 (4.9) | Laparoscopic sleeve gastrectomy | Women without PCOS undergoing bariatric surgery | 12 months |
| Casals et al[23] | 2021 | Cross-sectional | Spain | Rotterdam | 43 | 165 | 33.2 (4.9) | Laparoscopic Roux-en-Y gastric bypass, laparoscopic sleeve gastrectomy | Women without PCOS undergoing bariatric surgery | Up to 10 years |
| Chiofalo et al[22] | 2017 | Cohort | Italy | Rotterdam | 14 | 18 | Not reported | Sleeve gastrectomy, Roux-en-Y gastric bypass, gastric banding | Women without PCOS undergoing bariatric surgery | 12 months |
| Hu et al[14] | 2022 | Non-randomized trial | China | Rotterdam | 81 | 0 | 28.7 (0.7) | Laparoscopic sleeve gastrectomy | Women with PCOS receiving medical therapy | 12 months |
| Tatarchuk et al[15] | 2022 | Cohort | Ukraine | Rotterdam | 60 | 62 | 36.5 (3.2) | Gastric sleeve resection | (1) Women without PCOS undergoing bariatric surgery<br>(2) Women with PCOS managed conservatively | 15 months |

women with PCOS as well between women with and without PCOS. The remaining seven cohort studies[16–22] and the one cross-sectional study[23] compared outcomes following bariatric surgery between women with and without PCOS. All studies were published between 2016 and 2022. The types of bariatric surgeries performed were sleeve gastrectomy, Roux-en-Y gastric bypass surgery, gastric banding, and revisional bariatric surgery. Postoperative follow-up ranged from 6 to 24 months, with the exception of the cross-sectional study,[23] which assessed participants up to 10 years postoperatively.

### 3.2 | Participant characteristics

Collectively, 432 women with PCOS and 590 women without PCOS were studied. The number of women with PCOS included in each study ranged from 6 to 83 with the mean age ranging from 24 to 37 years. The Rotterdam criteria were used to diagnose PCOS in nine studies,[14–17,19–23] and the original NIH criteria were used in one study.[18]

### 3.3 | Risk of bias assessment

The overall risk of bias was determined to be high for all included studies (Figure 2). All studies were observational rather than randomized, and there were no studies in which outcome assessors were blinded to the exposure. The proportion of participants lost to follow-up and/or excluded from analysis was unclear or not reported in multiple studies.[15,19,22]

### 3.4 | Assessment of publication bias

There was no publication bias detected on visual inspection of the funnel plots (Supporting Information). However, this was challenging to assess given the meta-analyses were based on a small number of studies.

### 3.5 | Bariatric surgery versus pharmacotherapy

In the single non-randomized trial, participants receiving surgery achieved significantly better anthropometric outcomes compared to pharmacotherapy (i.e., metformin and combined oral contraceptive pill), including final weight (65.3 kg vs. 81.9 kg), final BMI (23.7 kg/m$^2$ vs. 30.1 kg/m$^2$), and final %TWL in those who experienced complete PCOS remission as defined by the study authors (34.3% vs. 8.3%) and those who did not experience complete PCOS remission (30.1% vs. 4.5%).[14] Of note, the surgical group had a statistically higher body weight (86.3 kg vs. 99.4 kg) and BMI (31.2 kg/m$^2$ vs. 35.6 kg/m$^2$) compared with the pharmacotherapy group at baseline. In this study, Hu et al[14] found that bariatric surgery was more effective than pharmacotherapy for reducing fasting glucose, fasting insulin, triglycerides,

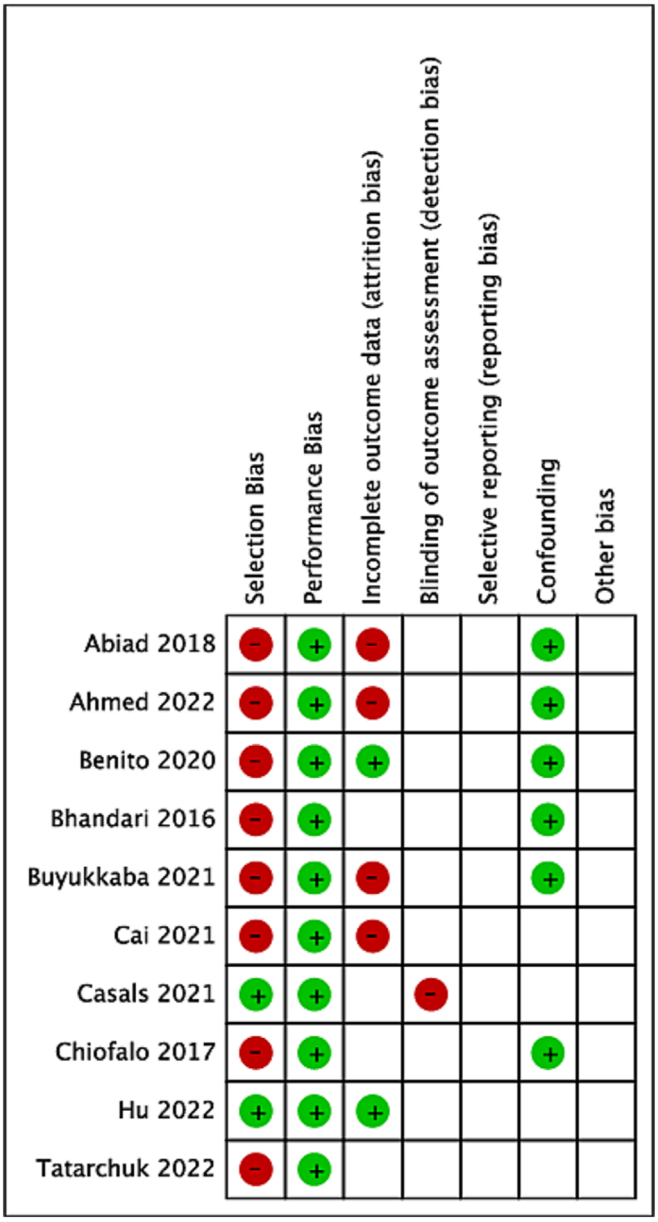


**FIGURE 2** Risk of bias assessment.

LDL-C, HbA1C, total testosterone, and SHBG. There were no significant differences in total cholesterol or HDL-C between groups. No studies assessed the effect of bariatric surgery compared to pharmacotherapy on reproductive outcomes in women with PCOS.

### 3.6 | Bariatric surgery versus lifestyle management

The single cohort study comparing bariatric surgery to lifestyle modification found that bariatric surgery was associated with higher %TWL compared with lifestyle modification (33.4% vs. 23.8%).[15] Compared with lifestyle management, bariatric surgery led to a shorter intermenstrual length and higher likelihood of ovulation.[15] No studies assessed metabolic or hormonal outcomes in women with PCOS following bariatric surgery compared to lifestyle management.

### 3.7 | Bariatric surgery in women with versus without PCOS

A meta-analysis was performed for the seven cohort studies that compared anthropometric outcomes between women with and without PCOS following bariatric surgery[15–21] (Tables 2 and 3). At baseline, anthropometric measures of body weight and BMI were similar between groups. There were no statistically significant differences between groups in %TWL, change in body weight or BMI, or postoperative body weight or BMI. When women with and without PCOS were compared in meta-analysis for metabolic and hormonal changes with surgery, there were no significant differences between groups at baseline. We found no significant differences in the change in metabolic or hormonal changes pre- and post-surgery for any outcomes aside from SHBG with bariatric surgery, which increased less in women with PCOS (MD −32.72 nmol/L, 95% CI −59.97, −5.46). Following bariatric surgery, women with PCOS had lower fasting glucose (MD −0.20 mmol/L, 95% CI −0.35, −0.06) and higher fasting insulin (MD 1.30 mU/L, 95% CI 0.24, 2.35) compared with women without PCOS. There were no differences in other metabolic or hormonal outcomes including lipids, HbA1c, or total testosterone between groups.

Three cohort studies assessed AMH after bariatric surgery in women with and without PCOS.[19,20,22] The women with PCOS had higher AMH levels at baseline compared with women without PCOS (MD 2.23 ng/mL, 95% CI 0.83, 4.84). A meta-analysis found no difference in postoperative AMH between the two groups.

In descriptive analysis, individual studies found that there were greater improvements in free testosterone, menstrual cycle regularity, ovulation, intermenstrual length, and pregnancy rates after bariatric surgery among women with PCOS compared to those without PCOS.[15,18,19] Additional pregnancy outcomes (e.g., pre-eclampsia, live birth) were reported in single studies (Supporting Information).

### 3.8 | The effect of bariatric surgery among women with PCOS

Anthropometric, metabolic, and hormonal outcomes were compared pre- and post-bariatric surgery among women with PCOS (Table 4). With bariatric surgery, women with PCOS had statistically significant improvements in body weight, BMI, fasting glucose, fasting insulin, total cholesterol, HDL-C, total testosterone, and SHBG. There were

**TABLE 2** Meta-analysis findings for postoperative anthropometric, metabolic, hormonal, and reproductive outcomes following bariatric surgery in women with PCOS compared to women without PCOS. Pooled effect estimates are shown where the outcome was measured by multiple studies. GRADE assessments were used to determine the overall certainty of findings.

| Outcome | Unit | No. of studies | *n* PCOS | *n* Non-PCOS | Effect estimateMD [95% CI] | *p*-value | Favors | Certainty |
|---|---|---|---|---|---|---|---|---|
| Body weight | kg | 5 (16, 18–21) | 151 | 236 | −3.30 [−6.97, 0.37] | 0.15 | None | ⨁◯◯◯ Very low |
| BMI | kg/m$^2$ | 5 (16, 18–21) | 128[a] | 189[b] | −0.94 [−2.08, 0.19] | 0.10 | None | ⨁◯◯◯ Very low |
| Fasting glucose | mmol/L | 3 (16, 18, 21) | 85 | 157 | −0.20 [−0.35, −0.06] | 0.006 | PCOS | ⨁◯◯◯ Very low |
| Fasting insulin | mU/L | 3 (16, 18, 21) | 85 | 157 | 1.30 [0.24, 2.35] | 0.02 | Non-PCOS | ⨁◯◯◯ Very low |
| Triglycerides | mmol/L | 3 (16, 20, 21) | 59 | 84 | 0.03 [−0.22, 0.29] | 0.81 | None | ⨁◯◯◯ Very low |
| Total cholesterol | mmol/L | 2 (20, 21) | 53 | 68 | 0.27 [−0.08, 0.62] | 0.13 | None | ⨁◯◯◯ Very low |
| HDL cholesterol | mmol/L | 3 (16, 20, 21) | 59 | 84 | −0.6 [−0.16, 0.04] | 0.21 | None | ⨁◯◯◯ Very low |
| LDL cholesterol | mmol/L | 3 (16, 20, 21) | 59 | 84 | 0.01 [−0.61, 0.63] | 0.98 | None | ⨁◯◯◯ Very low |
| Total testosterone | nmol/L | 3 (16, 18, 21) | 85 | 157 | 0.09 [−0.06, 0.23] | 0.87 | None | ⨁◯◯◯ Very low |
| SHBG | nmol/L | 3 (16, 18, 21) | 85 | 157 | −26.06 [−64.31, 12.19] | 0.18 | None | ⨁◯◯◯ Very low |
| AMH | ng/mL | 3 (19, 20, 22) | 95 | 105 | 1.57 [−0.29, 3.42] | 0.10 | None | ⨁◯◯◯ Very low |

*Note*: Casals et al[23] not included in the meta-analysis or *n* due to cross-sectional study design.
Abbreviations: AMH, anti-Mullerian hormone; BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SHBG, sex hormone binding globulin.
[a]The average BMI at baseline in the PCOS group in the included studies ranged from 38.1 to 46.37 kg/m$^2$.
[b]The average BMI at baseline in the non-PCOS group ranged from 36.9 to 46.79 kg/m$^2$.

**TABLE 3** Meta-analysis findings for change in anthropometric, metabolic, hormonal and reproductive health markers with bariatric surgery in women with PCOS compared to women without PCOS. Pooled effect estimates are shown where the outcome was measured by multiple studies. GRADE assessments were used to determine the overall certainty of findings.

| Outcome | Unit | No. of studies | *n* PCOS | *n* Non-PCOS | Effect estimateMD [95% CI] | *p*-value | Favors | Certainty |
|---|---|---|---|---|---|---|---|---|
| Change in body weight | kg | 4 (16, 18–20) | 121 | 215 | 0.52 [−4.66, 5.70] | 0.84 | None | ⨁◯◯◯ Very low |
| Change in BMI | $kg/m^2$ | 4 (16, 18–20) | 121[a] | 215[b] | 0.50 [−1.27, 2.27] | 0.58 | None | ⨁◯◯◯ Very low |
| %TWL | % | 2 (15, 17) | 57 | 91 | 4.29 [−4.13, 12.72] | 0.32 | None | ⨁◯◯◯ Very low |
| Change in fasting glucose | mmol/L | 2 (16, 18) | 55 | 136 | 0.13 [−0.19, 0.45] | 0.43 | None | ⨁◯◯◯ Very low |
| Change in fasting insulin | mU/L | 2 (16, 18) | 55 | 136 | 1.88 [−2.12, 5.88] | 0.36 | None | ⨁◯◯◯ Very low |
| Change in triglycerides | mmol/L | 2 (16, 20) | 29 | 63 | 0.80 [−0.92, 2.51] | 0.36 | None | ⨁◯◯◯ Very low |
| Change in HDL cholesterol | mmol/L | 2 (16, 20) | 29 | 63 | 0.01 [−0.38, 0.41] | 0.95 | None | ⨁◯◯◯ Very low |
| Change in LDL cholesterol | mmol/L | 2 (16, 20) | 29 | 63 | 0.41 [−0.95, 1.77] | 0.56 | None | ⨁◯◯◯ Very low |
| Change in total testosterone | nmol/L | 2 (16, 18) | 55 | 136 | −0.51 [−1.10, 0.08] | 0.09 | None | ⨁◯◯◯ Very low |
| Change in SHBG | nmol/L | 2 (16, 18) | 55 | 136 | −32.72 [−59.97, −5.46] | 0.02 | Non-PCOS | ⨁◯◯◯ Very low |

*Note*: Casals et al[23] not included in the meta-analysis or *n* due to cross-sectional study design.
Abbreviations: %TWL, percent total weight loss; BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SHBG, sex hormone binding globulin.
[a]Baseline average BMI in the PCOS group in the included studies ranged from 41.05 to 46.37 $kg/m^2$.
[b]Baseline BMI in the non-PCOS group in the included studies ranged from 40.54 to 46.79 $kg/m^2$.

no statistically significant differences between pre- and post-surgical values for triglycerides, LDL-C, or AMH.

### 3.9 | Adverse events

Two studies reported adverse events. Tatarchuk et al[15] reported no adverse events from bariatric surgery in women with and without PCOS. Hu et al[14] reported no adverse events from bariatric surgery or pharmacotherapy in women with PCOS.

### 3.10 | GRADE assessments

The certainty of all evidence using the GRADE tool was very low. Across the outcomes, risk of bias was considered high, as outcome assessors were not blinded to the exposure or intervention, yet this is not possible in surgical cohorts. The cross-sectional study relied on self-reporting of outcomes with potential non-response and recall bias.[23] Further, all outcomes were considered to have serious imprecision, given that many were based on a single study with a small sample size or had a wide confidence interval. There was no inconsistency or indirectness identified in included studies.

## 4 | DISCUSSION

Our systematic review identified 10 studies, including 432 and 590 women with and without PCOS, respectively, which assessed the impact of bariatric surgery in women with PCOS compared to a control group. Compared with pharmacotherapy and lifestyle management, bariatric surgery resulted in greater improvements in anthropometric outcomes. Given variability in outcome reporting, meta-analyses could only be performed for limited outcomes showing that women with PCOS experienced similar or improved anthropometric, metabolic, and hormonal outcomes after bariatric surgery compared with women without PCOS, with the exception of SHBG, which had greater improvement postoperatively in women without PCOS. Other significant differences in postoperative outcomes were reported by individual studies, but could not be pooled.

Although weight loss improves PCOS features including hyperinsulinemia,[7,24,25] weight loss strategies traditionally recommended for women with PCOS, including lifestyle modifications and pharmacotherapy, have limited reach, sustainability, and evidence of long-term efficacy. A review by Moran et al[26] identified four clinical trials assessing the effect of diet or exercise in women with PCOS with excess weight. Clinically significant weight loss (≥5%) was achieved by 62.7% of participants; however, attrition after less than

**TABLE 4** Meta-analysis findings for anthropometric, metabolic, hormonal and reproductive health markers pre- and post-bariatric surgery in women with PCOS. Pooled effect estimates are shown where the outcome was measured by multiple studies. GRADE assessments were used to determine the overall certainty of findings.

| Outcome | Unit | No. of studies | *n* | Effect estimateMD [95% CI] | *p*-value | Favors | Certainty |
|---|---|---|---|---|---|---|---|
| Body weight | kg | 5 (16, 18–21) | 208 | 30.03 [19.80, 40.25] | <0.00001 | Post-surgery | ⨁◯◯◯ Very low |
| BMI | $kg/m^2$ | 5 (16, 18–21) | 208 | 11.29 [7.73, 14.86] | <0.00001 | Post-surgery | ⨁◯◯◯ Very low |
| Fasting glucose | mmol/L | 3 (16, 18, 21) | 142 | 0.79 [0.23, 1.36] | 0.003 | Post-surgery | ⨁◯◯◯ Very low |
| Fasting insulin | mU/L | 3 (16, 18, 21) | 142 | 12.77 [5.23, 20.31] | 0.0006 | Post-surgery | ⨁◯◯◯ Very low |
| Triglycerides | mmol/L | 2 (16, 20) | 29 | 0.45 [−0.10, 1.00] | 0.11 | None | ⨁◯◯◯ Very low |
| Total cholesterol | mmol/L | 2 (20, 21) | 106 | 0.26 [0.01, 0.52] | 0.04 | Post-surgery | ⨁◯◯◯ Very low |
| HDL cholesterol | mmol/L | 3 (16, 20, 21) | 112 | −0.11 [−0.18, −0.04] | 0.004 | Post-surgery | ⨁◯◯◯ Very low |
| LDL cholesterol | mmol/L | 3 (16, 20, 21) | 112 | 0.13 [−0.13, 0.39] | 0.31 | None | ⨁◯◯◯ Very low |
| Total testosterone | nmol/L | 3 (16, 18, 21) | 142 | 0.54 [0.16, 0.91] | 0.006 | Post-surgery | ⨁◯◯◯ Very low |
| SHBG | nmol/L | 3 (16, 18, 21) | 142 | −20.36 [−30.42, −10.29] | <0.0001 | Post-surgery | ⨁◯◯◯ Very low |
| AMH | ng/mL | 3 (19, 20, 22) | 80 | −0.70 [−5.20, 3.81] | 0.76 | None | ⨁◯◯◯ Very low |

Abbreviations: AMH, anti-Mullerian hormone; BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SHBG, sex hormone binding globulin.

1 year was high at 47.1%. Similarly, a retrospective cohort study by Jensterle et al[27] assessed the use of metformin in women with PCOS and an overweight BMI. The mean decrease in body mass was 3.9 kg, but only 22% of individuals continued with metformin therapy for the intended 5-year follow-up period. There are limited data on newer pharmacotherapy options in PCOS, but effective, sustainable therapies are needed.

Furthermore, research has shown that patients rely less frequently on clinician recommendations for lifestyle strategies than they do on alternate sources. A recent cross-sectional study by Cowan et al[28] showed that among women with PCOS, ≤25% followed a dietary or physical activity plan prescribed by a healthcare provider, whereas ≥59% followed a dietary or physical activity plan found on the internet. Nearly half of these Internet-based plans were not consistent with established recommendations in PCOS, highlighting the need for evidence-based options.

Bariatric surgery is emerging as a potentially effective weight loss strategy for women with PCOS because of its substantial and sustained impact on weight. In the general population, bariatric surgery leads to greater absolute weight loss when compared to nonsurgical treatment options such as pharmacotherapy or lifestyle measures (MD −26 kg; 95% CI, −31 to −21).[28] Bariatric surgery has also been shown to improve metabolic parameters including fasting plasma glucose levels, insulin resistance, and incidence of type 2 diabetes.[29,30] In 2016, Skubleny et al[8] published a systematic review of the literature assessing the impact of bariatric surgery on PCOS. Thirteen case-series were identified, which included a total of 2130 females. The pooled preoperative incidence of PCOS was 45.6%, which decreased to 6.8% after surgery. Participants also experienced statistically significant improvements in menstrual irregularity, hirsutism, and fertility postoperatively.[8] While these findings are encouraging, a major limitation of the review by Skubleny et al[8] was that it did not formally report study quality. Included studies had significant variation in PCOS diagnostic criteria, outcomes reported, and many studies did not include a comparison control group.[8] Notably, none of the studies included met inclusion criteria for the present study. This highlights the lack of quality studies in PCOS more broadly, despite difficulty losing weight being the number one concern for women with PCOS.[31]

Our review sought to provide an updated summary of the evidence for bariatric surgery in PCOS. Given the number of newly published studies and the increased interest in bariatric surgery as a strategy for improving PCOS features, an updated evidence synthesis was pertinent to guide clinical recommendations in this area. All included studies were published from 2016 onward. Overall, women with PCOS can expect comparable health outcomes to women without PCOS following bariatric surgery. In PCOS populations specifically, while the existing evidence suggests that bariatric surgery may

be more effective than lifestyle and pharmacotherapy treatments in achieving weight loss and improving hormonal and metabolic abnormalities in women with PCOS, available studies are of limited number and quality.

A recent prospective observational study assessed the impact of bariatric surgery on clinical, hormonal, and metabolic outcomes in women with PCOS in India.[32] While this study did not have a comparison group and thus did not meet our inclusion criteria, it followed 1013 patients with PCOS postoperatively for up to 5 years. Over 90% of participants had at least moderate resolution of hirsutism and menstrual dysfunction by 1 year after bariatric surgery. Nearly 80% with hypertension or type 2 diabetes preoperatively were normoglycemic (79.7%) and normotensive (78.8%) at 6 months' post-surgery. In addition, dyslipidemia and obstructive sleep apnea had resolved in >90% of participants at 5 years. These results are encouraging but need to be replicated in other populations and in quality trials.

Despite its promising benefits in PCOS, bariatric surgery is a major procedure with the potential to cause unintended consequences and complications. A 2019 systematic review and meta-analysis by Akhter et al[33] highlighted that while women undergoing bariatric surgery prior to pregnancy were less likely to experience gestational hypertension and diabetes, there was a significantly increased risk of adverse perinatal outcomes, including perinatal mortality, congenital anomalies, preterm birth, small-for-gestational age, and neonatal intensive care unit admission.[33] The proposed underlying mechanism was a deficiency in nutrients essential to fetal development due to alterations of the gastrointestinal tract. A cohort study by Damti et al[34] which assessed 1001 offspring of mothers who had undergone bariatric surgery found that they were at increased risk of endocrine morbidity, specifically pediatric obesity, compared to both women with obesity who had not undergone bariatric surgery and women without obesity. There is limited evidence on pregnancy- and neonatal-related outcomes for women with PCOS who undergo bariatric surgery. Current guidelines recommend contraception in the form of a long-acting reversible contraceptive (e.g., intrauterine devices, etonogestrel implants) be started prior to bariatric surgery and continued for a minimum of 12 months after surgery.[35] Further research in this area is needed to enable informed, shared decision-making.

The limitations of the literature are evident, with high risk of bias demonstrated across all existing studies. Bariatric surgery is a relatively uncommon procedure, often with small sample sizes, and a clear need for a large-scale, multicenter, high-quality trial of bariatric surgery in PCOS, ideally embedded in surgical registries. While important, blinding and randomization are not relevant in this context given that this is challenging, if not impossible to achieve, due to the nature of bariatric surgery, its associated risks, and its benefits outside of PCOS. Nevertheless, blinding of outcome assessors is possible (e.g., lab personnel) and should be incorporated in future studies. The retrospective design of all included studies lends itself to multiple added sources of bias. The number of participants lost to follow-up was generally high or not reported by many studies, leading to further potential for bias. Other limitations include considerable heterogeneity in findings, variation in the surgical interventions included, and variable individual physician and patient factors. The outcomes assessed postoperatively also vary and are measured and reported differently. Duration of follow-up is inconsistent, ranging from 6 to 24 months. Overall, benefits appear to be important, but the evidence is of poor quality and very low certainty.

Some limitations and strengths of the review should also be noted. Our search did not include grey literature or studies that were not published in the English language or not available in full text. Hence, some studies may have been missed and publication bias cannot be ruled out. We performed subgroup analyses to determine the effects of bariatric surgery among women with PCOS and without PCOS; however, these pooled estimates should be interpreted with caution as they only include outcomes from studies included in our systematic review, which excluded studies that reported pre–post analyses of bariatric surgery in women with PCOS without a comparator. Due to heterogeneity and limited data, meta-analysis was not possible for all outcomes or comparisons, and we could not perform meta-regression to examine potential effect modifiers. These may influence results and should be considered in future meta-analyses with larger numbers of studies/participants. Notwithstanding these limitations, our review included a comprehensive search of five databases, with international gold-standard methodology, endorsed by the guideline overseeing national bodies (National Health and Medical Research Council). Our methods also conform to standard reporting guidelines (PRISMA) and use validated assesses sent tools (Cochrane risk of bias, GRADE) with a protocol registered publicly a priori for transparency (PROSPERO). Outcomes were determined and prioritised via consultation with content experts in the guideline development group and with patients via public consultation and consumer surveys.[9]

## 5 | CONCLUSION

PCOS is a common disorder, with higher rates of excess weight, in turn exacerbating the condition and its related features. Excess weight is the topmost concern for affected women. In addition to lifestyle and pharmacotherapies, bariatric surgery holds promise as an intervention to reduce excess weight, improve the reproductive, metabolic, and hormonal features of PCOS, and potentially even resolve the condition in some women with excess weight. However, existing literature on this topic is limited and highly susceptible to bias, with inherent challenges around traditional measures of study quality including randomization and blinding in controlled trials. Efforts to prioritize funding, improve quality, minimize bias, and facilitate comparison between studies is key moving forward. These include using prospective multicenter, controlled study designs, consistent PCOS diagnostic criteria, harmonized outcomes, and reporting losses to follow-up. Clear research priorities, coupled with high-quality studies, can advance research in this area and provide more definitive evidence to inform clinical recommendations and improve shared decision-making for bariatric surgery in PCOS.

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## CONFLICT OF INTEREST STATEMENT

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## SUPPORTING INFORMATION

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