Review

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Review

The Effects of Bariatric Surgery on Female Fertility: A Narrative Review Article

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Abstract

Background/Objectives: Obesity is a growing global health concern with significant implications for female reproductive health, notably contributing to menstrual irregularities, anovulation, and infertility. This review explores the relationship between female obesity and reproductive dysfunction, with a particular focus on the impact of bariatric surgery on fertility outcomes. **Methods:** Drawing from 116 original research studies, the analysis examines the two bariatric surgical techniques, sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB), and their effects on weight loss, hormonal profiles, ovulatory function, and conception rates. **Conclusions:** Results consistently demonstrate improvements in menstrual regularity, resolution of polycystic ovary syndrome (PCOS) symptoms, including improved insulin sensitivity and reduced hyperandrogenism, increased spontaneous ovulation and enhanced fertility following significant post-surgical weight reduction. Additionally, timing of pregnancy after surgery, type of surgical intervention, and degree of weight loss are identified as critical determinants of reproductive success. The review also addresses gaps in long-term data and emphasizes the need for individualized preconception counseling in women with obesity pursuing fertility.

Keywords: bariatric surgery; obesity; female fertility; insulin resistance; polycystic ovary syndrome; pregnancy; sleeve gastrectomy; Roux-en-Y gastric bypass

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1. Introduction

The prevalence of obesity worldwide has almost tripled between 1975 and 2016. In 2016, 1.9 billion adults aged 18 years and older (40% of women and 39% of men) were classified as overweight with Body Mass Index (BMI) 25,0-29,9 kg/m2, and 650 million (11% men and 15% women) being obese with a BMI of ≥ 30 kg/m[1,2]. According to definition obesity is a disease characterized by accumulation of excess body fat, which in turn leads to pathogenesis; is determined by BMI greater than 30 kg/m2[3]. Overweight and obesity is characterized as one of the most important health problems worldwide. Conditions such as type II diabetes Mellitus, dyslipidemia, hypertension, coronary heart disease, gallstones, breast and endometrial cancer during menopause, as well as fertility disorder in reproductive age, are often found in overweight obese women [4,5]. Based on international guidelines, patients with class III obesity (BMI ≥ 40 kg/m2) or obesity class II (BMI 35-39 kg/m2) with comorbidities are candidates for bariatric surgery (BS) [6]. BMI thresholds should be adjusted in the Asian population such that a BMI ≥25 kg/m2 suggests clinical obesity, and individuals with BMI ≥27.5 kg/m2 should be offered Metabolic Bariatric Surgery (MBS) [6].

According to the American Society of Reproductive Medicine Committee, (ASRM) infertility is a disease generally defined as failure to conceive after 12 or more months of natural fertilization

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attempts. World Health Organization (WHO) estimates that this pathology currently affects 50-80 million women, which in many cases can reach 50% of all women; however, for women over 35 years of age, time data and investigation approach differ (which is not a topic of analysis of this work) [7]. As far as couple is concerned, infertility is estimated to affect about 70 million couples worldwide [7]. Following an analytical report, the lifetime infertility rate in Eastern Mediterranean countries is estimated at 3,3%-21,3%, in England 7% and in African countries at 30% [8]. Taking into account recent fertility methods, total population growth will reach zero in the period 2036-2041[8]. At the same time, infertility is characterized as a disease that is a growing social problem today and seems to affect obesity with different mechanisms. Obesity and infertility, public health issues, which cause global concern, show more often their close relationship between women of reproductive age [9].

Global BMI trends show sustained increases among girls and women across regions, reinforcing the large reproductive-age population affected by obesity [2]. The fertility rate of obese women compared to normal weight women is lower in natural cycles and infertility treatment cycles [10]. Higher rates of miscarriage and congenital anomalies are also reported for this group of women [11]. Women who have a higher BMI before pregnancy (higher than 25kg/m2) have a higher rate of difficulty in achieving fertilization - pregnancy progression as well as miscarriages or extremely premature birth, compared to the group of women who are ideally BMI rates in the range of 20.0kg/m2 -24.9kg/m2 [9,12,13]. In contrast, women who follow a regular weight loss program have been shown to improve their menstrual cycle, the ovulation rate monthly and therefore increase the likelihood of fertilization, conception and pregnancy [9].

Obesity can be treated with weight loss due to dietary intervention, physical activity, use of weight reduction drugs, or metabolic-bariatric surgery (MBS) [9,14]. MBS has become a treatment of interest in the management of obesity. It is accepted that it leads to more than 20% of total weight loss [15,16] which is enough to improve Polycystic Ovarian Syndrome (PCOS), diabetes and hypertension [17]. It has been shown to improve fertility and pregnancy-related outcomes for mother and child [18]. The most common bariatric surgery (BS) procedures include Roux-en-Y gastric bypass (RYGB), vertical sleeve gastrectomy (VSG), accounting for approximately 90% of all operations performed worldwide [6]. According to National Institute for Health and Clinical Excellence (NICE) guidelines, current indications for bariatric surgery include a BMI greater than 40 kg/m2 or greater than 35 kg/m 2 with significant complications related to obesity, such as type 2 diabetes Mellitus (T2D) or hypertension [6]. MBS delivers the most durable weight loss with broad cardio metabolic risk reduction relative to lifestyle or medications in severe obesity [19].

The purpose of this study is to review the effects of bariatric surgery (RYGB, VSG) into female fertility, AMH levels, hormonal profile, insulin resistance, time to conception, ovulation, pregnancy rates.

2. Methods - Description of the Literature Search

This narrative review was developed based on search for studies published up to September 2025 in PubMed, Scopus, Web of Science, in order to include data relevant to Bariatric surgery on female fertility. The search was limited to English language articles. The search strategy included combinations of the keywords "fertility", or "female fertility", or "reproductive function", or "IVF", or "AMH", or ' 'PCOS", or "pregnancy", or "live birth rates", or "female obesity", or ''female infertility'', or ''timing to conception'' AND "metabolic surgery", or "bariatric surgery", or "RYGB", or "VSG", or "SG", or "weight-loss surgery" Publications and guidelines were screened including the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO), the British Obesity and Metabolic Surgery Society (BOMSS) and the American Society for Metabolic and Bariatric Surgery (ASMBS). All retrospective, prospective and meta-analysis articles were considered, reviewed in full and were summarized to be included as relevant to the scope of the present narrative review, as detailed in the following sections.

3. Obesity and Infertility in Women

Obesity is a complex, chronic disease characterized by excessive accumulation of adipose tissue, which increases the risk of long-term medical complications and reduces life expectancy [20]. Obesity reduces natural and assisted reproductive technology (ART) fecundity and increases miscarriage, and infertility in women. It is tightly linked with psychological morbidity and demands comprehensive, multidisciplinary, and equity-minded care [7,21]. Furthermore, fertility disorders are commonly observed in overweight and obese women of reproductive age [5]. In the United States, 36.5% of women between the ages of 20 and 39 are affected by obesity [20].

Women with obesity have lower per-cycle and cumulative conception probabilities, longer time-to-pregnancy, and reduced IVF success with higher miscarriage risk; estimates include 5% lower probability of pregnancy per BMI unit above 29 kg/m² and 10% lower IVF success in overweight women [15]. This aligns with cohort data in women where even "normal-range" higher weight and adult weight gain increase Coronary Heart Disease (CHD) risk [4], underscoring the reproductive-health value of preventing/treating obesity.

A systematic review and meta-analysis reported higher odds of psychological distress (OR 1.63) and depression (OR 1.40) in infertile women, and smoking nearly doubled infertility odds [21]. In low-resource settings, infertility in women carries severe social consequences (stigma, isolation, violence) highlighting equity gaps [7,21].

Obesity and morbid obesity are associated with significant alterations in the hypothalamic-pituitary-ovarian (HPO) axis, as well as, with clinical manifestations such as hirsutism, menstrual irregularities, endometrial dysfunction, and gestational complications-including an increased risk of miscarriage [22,23].

The outcome of ART cycles also appears to be negatively affected. Obese women tend to have fewer, smaller, and less mature oocytes, resulting in reduced fertilization rates [24].

The primary mechanism linking obesity to female infertility is insulin resistance (IR) and the consequent hyperinsulinemia, which disrupts normal reproductive endocrine function [25]. Another important contributor to anovulation is obesity-associated hyperleptinemia, which not only promotes hyperinsulinemia but also has a direct negative impact on ovarian function. Leptin, an adipokine produced in adipose tissue, interferes with steroidogenesis in granulosa cells and inhibits folliculogenesis in a dose-dependent manner [26,27].

Moreover, variations in gonadotropin-releasing hormone (GnRH) pulsatility, reduced sex hormone-binding globulin (SHBG) levels, and alterations in ovarian and adrenal androgens and luteinizing hormone (LH) levels may further contribute to reproductive dysfunction in obese women [9].

Finally, lipotoxicity and a chronic low-grade inflammatory state, common in obesity, negatively impact reproductive capacity, endometrial receptivity, and embryo development, further reducing the chances of successful implantation and pregnancy [27,28].

However, the adverse effects of obesity appear to be more pronounced in women with PCOS, whose prevalence in Western countries is estimated at approximately 5% to 10% [27,29].

According to a cohort study involving ovulatory sub-fertile women, the probability of natural conception over a 12-month period decreased by 4% for each 1 kg/m² increase in BMI above 29 kg/m² [30,31].

Observational evidence synthesized for women shows improved ovulation, menstrual regularity, and conception post-bariatric surgery; pregnancy should be delayed 12-18 months and supported by robust micronutrient care once pregnant [15]. Complementary lifestyle optimization around ART is being tested in a protocolized RCT framework.[8]

4. Female Obesity, Fertility and Bariatric Surgery (BS)

For women with obesity, Bariatric surgery (BS) is guideline-endorsed for durable weight loss and broad risk reduction;[6] in reproductive care it improves fertility and pregnancy-related risks when combined with careful timing to conception, contraception, and micro-nutrient management [15].

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Female patients of reproductive age comprise 65% of BS in USA every year [32]. BS improves fertility and some medical disorders related to pregnancy, provided that lifestyle changes and pharmacological treatment management have been unsuccessful [14]. It is accepted that it leads to more than 20% of the total body weight loss, which is enough to improve PCOS, diabetes and hypertension [17]. Based on international guidelines, patients aged 18y-60y with obesity class III (BMI >40Kg/m2) or obesity class II (BMI:35,0-39,0Kg/m²) and comorbidities may be eligible for BS [33]. The joint American Society for Metabolic and Bariatric Surgery (ASMBS) and International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) 2022 statement recommends BS for BMI ≥ 35 kg/m² regardless of comorbidities, and to consider BS for BMI 30-34.9 kg/m² with metabolic disease; Asian thresholds are lower [6]. Almost 60% of female patients undergoing major BS are between 20-44 years of age and these women need appropriate management advice on contraception, nutrition and supplementation before conception and weight management during and after pregnancy [15]. BS still remains a safe treatment option for obesity, resulting in reduction of complications associated with maternal obesity [34].

The three main classes of BS include restrictive, malabsorptive and combined restrictive-malabsorptive procedures. Restrictive procedures, such as sleeve gastrectomy (SG), vertical banded gastroplasty (VBG) (also, called Stomach stapling) and its newer modification named silactic Ring Vertical Gastroplasty (SRVG), and adjustable gastric banding (AGB), promote weight loss by decreasing gastric volume into a smaller tube-like shape in order to reduce food intake. Restrictive procedures also promote a shorter mean time of rapid weight loss than combined procedures (9-12 months vs. 12-18 months) [35].

In the United States, most techniques are combinatorial with the Roux-en-Y gastric bypass (RYGB) accounting for 93% of all procedures performed in 2000; increased from 55% in 1990 to 93% in 2000 [36]. In a recent 10-year follow-up of a randomized study of laparoscopic RYGB and laparoscopic adjustable gastric banding (LAGB) was shown LRYGB to be superior to LAGB in terms of weight loss (76.2% vs. 46.2%), but exposed the patient to higher complication rates as well as long-term fatal surgical complications [37]. While, sleeve gastrectomy (SG) is the most common bariatric metabolic procedure, accounting for more than 60% of both total and primary procedures globally [38]. Effective and durable weight loss is the most important change after SG [39].

It is still unknown which procedure is the optimal one for the weight reduction in female obesity as far as infertility is concerned [40]. BS is believed to improve conception rates; especially after weight loss was increased to 67% (95% CI= 47-87%, P-value <0.05). This improvement is likely due to positive changes in women's hormone profiles, menstrual regularity, and ovulation [41]. In severe obesity, BS is the most durable option and may restore fertility when decided appropriately [6,15].

Evidence summarized for women indicates lower risks of gestational diabetes and hypertensive disorders compared with persistently obese controls, with individualized antenatal pathways (e.g., alternative Gestational Diabetes Mellitus (GDM) testing after RYGB; fetal growth surveillance when risk factors exist) [15]. Post-surgical weight loss improves dyslipidemia, blood pressure, glycaemia, inflammation, and sleep apnea, mechanisms that plausibly reduce long-term Cardiovascular Disease (CVD) events and mortality [19].

4.1. Female Fertility and Roux-en-Y Gastric Bypass (RYGB)

4.1.1. Roux-en-Y Gastric Bypass (RYGB) Mechanism

RYGB is a mixed bariatric surgical procedure (restrictive and malabsorptive) in which the stomach volume is reduced to approximately 15-30 mL [42]. The gastric pouch is anastomosed to the jejunum after it has been divided some 30 to 75 cm distal to the ligament of Treitz; this distal part is brought up as a 'Roux-limb'. The excluded biliary limb, including the gastric remnant, is connected to the bowel some 75 to 150 cm distal to the gastrojejunostomy [42]. Nutrient absorption is affected by bypassing a portion of the small intestine and rerouting the flow of food to the longer segment of the small intestine. This mechanism not only leads to limited oral food intake but also causes

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malabsorption, which tends to decrease over time due to intestinal hypertrophy [43]. Furthermore, an increase in the secretion of gut hormones (including GLP-1 and PYY) following RYGB contributes to reduced appetite and leads to glucose homeostasis [44]. RYGB was first introduced by Mason in 1966 and, nowadays, is accepted to be (along with sleeve gastrectomy) as one of the most reliable bariatric surgical method performed worldwide, with consistent long-term outcomes [45,46].

4.1.2. Effects of RYGB on Ovarian Reserve and Anti-Müllerian Hormone (AMH) Levels

Several studies have evaluated the relationship between RYGB and anti-Müllerian hormone (AMH) levels, as a marker of ovarian reserve, showing mixed results. Some studies indicate that AMH concentrations decrease postoperatively, whereas, others reported improvements in fertility after bariatric surgery [47].

A study in 16 obese women before and after RYGB revealed a significant 23.9% decrease in AMH levels among patients under 35 years old, whereas BMI decreased by 14.5%. No significant change was found in women aged ≥35 years, who already had very low preoperative and postoperative AMH levels (<1 ng/mL for group 2, <0.1 ng/mL for group 3). The authors suggest that this decline may be related to some effects of the surgery (postoperative stress or malabsorption of micronutrients affecting AMH gene expression) [47]. (Table 1)

A prospective cohort study involving 48 women aged 18-35 years with morbid obesity (mean BMI 40.9 ± 3.6 kg/m²) analyzed AMH levels before and after RYGB [48]. AMH concentrations increased significantly after a very low-calorie diet (VLCD) prior to surgery (from a median of 30.0 pmol/L to 35.0 pmol/L; $P = 0.014$), but decreased at 6 and 12 months postoperatively (19.5 pmol/L and 18.0 pmol/L, respectively; $P = 0.001$) (Table 1). Similarly, the free androgen index (FAI) decreased significantly after 12 months (1.2 vs. 3.5, $P < 0.0005$). This decline surpassed the expected 5.6% annual age-related decrease in AMH levels [49].

A retrospective study of 39 women (18-45 years) who underwent sleeve gastrectomy (SG) or RYGB (23 SG, 16 RYGB; only 6 with PCOS) also showed a significant reduction in AMH levels by 18% at 6 months and by 35% at 12 months postoperatively ($p = 0.010$ and $p = 0.001$, respectively), independent of excess weight loss . The authors hypothesized that postoperative follicular stress could explain the decline, and emphasized the need for long-term studies to clarify the impact on ovarian reserve [50]. (Table 1)

A recent systematic review published in 2023, including 8 studies with 547 participants, confirmed that laparoscopic RYGB (LRYGB) results in substantial excess weight loss and reductions in testosterone levels at 6 and 12 months, thereby improving the metabolic and hormonal profile of women with PCOS [51], (Table 1).

4.1.3. Hormonal and Metabolic Improvements After RYGB

RYGB induces major improvements in insulin sensitivity and hyperandrogenism in women with PCOS. According to a study by Eid GM et al. [52], 24 women with PCOS (mean age 34 years, BMI 50 ± 7.5 kg/m²) underwent LYGB. The mean excess weight loss (EWL%) at one year was 56.7 ± 21.2%. All participants resumed regular menstrual cycles within a mean of 3.4 ± 2.1 months, while 52% achieved complete resolution of hirsutism, and 5 patients conceived spontaneously postoperatively. These findings demonstrate significant restoration of reproductive function [52] (Table 1).

Escobar-Morreale et al. [53], also reported similar outcomes in a cross-sectional study of 36 premenopausal women, 19 of whom underwent LYGB; 17 were diagnosed with PCOS. Participants showed a remarkable improvement in insulin resistance from 5.79 ± 2.78 to 1.6 ± 1.0 ($P < 0.001$), supporting the metabolic benefits of RYGB in reproductive-aged women [53] (Table 1).

Importantly, AMH levels have been associated with insulin resistance and androgen levels in both PCOS and non-PCOS women [54]. Lifestyle-based weight loss alone does not significantly alter AMH levels [55]; however, hypocaloric diets combined with sibutramine improved hyperandrogenemia and insulin sensitivity while decreasing AMH [56]. Thus, the decline in AMH and testosterone after RYGB may reflect enhanced insulin sensitivity rather than reduced ovarian reserve [57].

4.1.4. Fertility and Pregnancy Outcomes After RYGB

Jamal M. et al. [58] studied 566 morbidly obese women who underwent RYGB (2000-2009), among whom 31 (5.5%) had PCOS (mean age 32 ± 5.8 years, BMI 52.8 ± 9.08 kg/m²). Postoperatively, 82% experienced normalized menstrual cycles, hirsutism resolved in 29%, and 77.8% of those with diabetes achieved complete remission. Of 10 women who had not conceived before surgery, 6 became pregnant within 3 years (5 spontaneously, 1 via intrauterine insemination), despite the medical recommendation to avoid conception for 18 months postoperatively. The conception rate of 100% within 3 years is noteworthy, highlighting RYGB's strong fertility-enhancing effect in PCOS. (Table 1)

While a meta-analysis by Chang et al. [59], leads to a conclusion that patients who underwent Bariatric Surgery were more than twice as likely to achieve pregnancy compared to those treated with metformin only.(34.9% vs.17.1%) According to 10 studies[Metformin: 5 studies, n=192; BS: 2 studies with RYGB, 2 studies with SG, and 1 study with RYGB + SG, n=186) the metformin group compared to the BS group (average follow-up time: Metformin: 11.2 vs BS: 24.5 months) increased the likelihood of pregnancy compared to placebo or non-surgical interventions (OR=3.08, 95% CI 1.29-7.37,p=0.01), while the pregnancy rate after BS was greater than metformin (34.9%, 95% CI 0.20-0.53 vs 17.1%, 95% CI 0.12-0.23, p=0.026 for the difference). Additionally, there was an improvement in menstrual disorders in the surgical group compared to the metformin group with a reduction of 92% in the bariatric cohort compared to a reduction of 54% in the metformin cohort, but data were limited. (Table 1)

Based on a retrospective cohort study, both LSG and LRYGB are effective and safe in improving fertility, achieving significant weight loss, and supporting favorable pregnancy outcomes in morbidly obese women, in 5 years of follow up [60]. 79 females with morbid obesity underwent LSG (n = 38) or LRYGB (n = 41); no recorded maternal or neonatal complications specifically attributed to diabetes or hypertension during pregnancy or childbirth. It was evaluated as the percentage excess weight loss (%EWL), improvement of comorbidities, postoperative complications or mortality, and fertility outcomes; Fertility outcomes were assessed in three subgroups: primary infertility (n = 21), secondary infertility (n = 8), and pre-marriage patients (n = 50) (Table 1, Table 3)

4.1.5. RYGB Effects on Long-Term Hormonal and Reproductive Function

A prospective cohort study, of 106 women (85 women RYGB, 21 women laparoscopic gastric banding; median BMI 44.5) investigated changes in sexual function and reproductive hormones over 2 years postoperatively. Participants lost ~33% of initial body weight and reported significant improvements in sexual desire, arousal, lubrication, and satisfaction. Hormonal analyses showed reduced in total testosterone levels, increased SHBG and estradiol, and overall improvement in reproductive hormones' levels [61] (Table 1)

Contrarily, a prospective cohort study [62], involving 29 reproductive-aged women who underwent RYGB found that ovulation rates (initially 90%) and ovulation quality remained unchanged after surgery. While hormonal markers such as SHBG increased (P<.001), testosterone and estradiol decreased (P=0.002 and P=0.03 respectively), indicating a shift toward hormonal normalization rather than suppression of ovulatory function (Table 1).

Notably, RYGB outcomes appear durable, with 10-year follow-up studies reporting sustained 20% body weight loss in 73.5% of female patients [16,63]. However, if postoperative reductions in AMH reflect a real decline in ovarian reserve, clinicians should consider fertility preservation counseling for reproductive-aged women before bariatric surgery [50].

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Table 1. Clinical, hormonal and fertility outcomes of RYGB bariatric surgery in women with obesity.

Ref. No	Sample size	Age (years)	Time Point	BMI (Kg/m2)	Weight Loss (kg)	Parameter	Surgical procedure	Fertility outcome	Country	Follow-Up
[52] Eid et al. (2005) Retrospective cohort	24 PCOS women	34y ± 9.7y	Pre-op 12-57 months	50 ± 7.5	56.7% ± 21.2%.	Hirsutism, irregular menstrual cycles, infertility	LYGB	5 infertile pre-op conceive no aid of clomiphene. 75% complete resolution of hirsutism improvement with type II diabetes mellitus, hypertension, & dyslipidemia. 1 y mean post-op BMI 30 ± 4.5 Menstrual dysfunction pre-op 24 PCOS 100% change post-op	USA	27.5 ± 16.5 months
[53] Escobar-Morreale et al. (2005) cross sectional study	36 premen/sal obese women (17 obese PCOS women)	27y ± 1.5y (obese PCOS group)	Pre-op 6 months post-op	37.1 ± 1.5	41 +/- 9 kg	Hyperandrogenism, (hirsutism score 9.5 ± 6.8 to 4.9 ± 4.2) insulin resistance 5.79 ± 2.78 to 1.6 ± 1.0, menstrual function.	LYGB (19 women)	restoration of regular menstrual cycles, ovulation in all patients, improvement in insulin resistance Hyperandrogenism	Spain	6 months 12 ± 5 months
[47] Mehri et al. (2008) Prosperity cohort study	16 obese women	Group 1: 29.5y ± 1.0 (n=7) & Group 2: 40.5y ± 2.4 (n=4) & Group 3: 51.2y ± 2.8 (n=5)	Pre-op and mean 87±30 days post-op	Group 1: Pre 50.2, Post 42.9 Group 2: Pre 44.4, Post 35.8 Group 3: Pre 48.7, Post 42.9	Not directly reported (14.5-19.4% drop)	AMH Group 1: Pre:3.8 & Post:2.9, Group 2: Pre:0.63 & Post:0.80, Group 3: Pre:0.10 & Post:0.10 History of PCOS: Group 1: Yes 1, No 6, Group 2: Yes 1, No 3, Group 3: Yes 0, No 5	RYGB LAGB	AMH ↓ 23,9% in women <35y post-op no change in older groups; no direct fertility data; implications on ovarian reserve	USA	~3 months post-op

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[58] Jamal et al. (2011) Retrospective cohort with interviews	566 morbidly obese women	32y ± 5.8 y	Base line	52.8 ±9.08 kg/m2 (range 37-76) pre-op	mean %EWL 64%, (26% in the first month post-oper)	31 (5.5%) PCOS 50% of the patients with PCOS infertile, 85% menstrual dysfunction, 70% had hirsutism, 45% T2DM, 40% depression	RYGB	menstruation corrected in 82%, hirsutism resolved in 29%, 77.8% of those with diabetes had complete remission, 100% conception rate within 3y of surgery	USA	46.7 ± 35.3 months
[62] Legro et al. (2012) Prospective cohort	29 obese women	18y-40y	Base Line 1 m, 3 m, 6 m, 12 m, 24 m	49 -6 -11 -15 -18 -19	 -15 -29 -40 -50 -51	ovulation frequency/quality Ovarian volume (BL) 16.1±13.1 (6m) 17.2±9.4 (12m) 13.3±6.4 MCL(d) 37.2 -2.5 -2.9 -6.0 -4.4 -4.1 FPL(d) 22.0 -3.2 -6.5 -8.2 -7.9 -8.9 LPL(d) 12.2 3.8 0.0 0.8 0.8 0.0	RYGB	Ovulatory cycles %, BL 90%, 1m 9.9%, 3m 10%, 6m10.1%, 12m10%, 24m 0.98% SHBG ↑ TESTO ↓ E2 ↓	USA	24 months post-oper
[61] Sarwer et al. (2014) Prospective cohort	106 morbid obese women	34y-48y	Model based estimates, mean Base Line: 1 yr, 2 yrs	44,5	32.7% (95% CI, 30.7%-34.7%) (1 yr), 33.5% (95% CI, 31.5%-35.6%) (2 yrs)	E2 pg/ml 86.9/51.4/53.1 -35.5/-33.8/1.7 total testo ng/dl: 47.8/30.4/23.1/-17.4/-24.7/-7.3 FSH mIU/ml: 15.3/22/29.9/6.7/14.6/7.9	LYGB (85) 80.2% AGB (21) 19.8%	improvements in sexual functioning, reproductive hormone levels,	USA	2 yr

			model based mean changes (95%CI): yr 1 from BL, yr 2 from BL, yr 2 from yr 1			LH mIU/ml: 9.4/13.3/15.9/3.9/6.5/2.6 SHBG μg/ml: 4.8/11.4/9.8/6.6/4.9/-1.6 DHEAs μg/ml: 118.6/106.1/92.6/-12.4/-26.0/-13.6				
[48] Nilsson-Condori et al. (2018) Prospective cohort	48 Morbid obese women	18y-35y	Baseline, pre-surgery (post-diet), 6months, 12monts postop	40.9 (38.6 after VLCD) → 25.4 (6.4) (post-op)	After VLCD 110.3 ~41.7, 75.5 (after 12 months)	AMH and FAI/AMH 30.0 (Base Line) 35.0 (after VLCD) 19.5 (6m), 18.0 (12m) Testosterone 1.1 after VLCD, 1.0 after 6m, 0.9 after 12m LH 6.1, 5.9 after VLCD, 5.9 after 6m, 5.3 after 12m FSH 5.5, 4.8 after VLCD, 4.2 after 6m, 4.3 after 12m SHBG 28.0, 39.5 after VLCD, 67.0 after 6m, 73.0 after 12m	RYGB	↓AMH; ↓FAI (suggesting improved fertility). 2y after improvements in overall sexual functioning (arousal, lubrication, desires, and satisfaction).	Sweden	12 months (post-op)
[50] Vincentelli et al. (2018) Prospective cohort	39 obese women, 6 PCOS, 79% morbid obesity	18y-45y	Base Line 6 months 12 months	45.4 33.6 31.4	 61.7 70.2	AMH 13.4 11.2 10.5	LYGB (16) SG (23)	↓in AMH negative impact of BS on ovarian reserve	France	12 months (post-op)

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[59] Chang et al. (2020) Retrospective cohort survey - meta-analysis	Metformin: 5 studies, n = 192; BS: 5 studies n = 186	33y-40y	22 months post-op	Pre-op: 44.5 (mean)	27.3% (mean EWL)	Pregnancy and infertility history questionnaire	RYGB (2) SG (2) RYGB+SG (1)	Pregnancy rate 13.3% to 53.6% post-op; infertility, 18.8% to 5.4%. pregnancy rate BS vs metformin, 34.9% vs 17.1%. Improvement in menstrual disorders BS vs metformin ↓92% vs ↓ 54%	Taiwan	22 months post-op (mean)
[51] Ghobrial et al. (2023) Prospective cohort	547 obese PCOS women	30y-41y	Pre-op 6 & 12 months postop	Pre-op mean: 43.7 ± 6.1	EWL in 8 studies	Serum AMH, hormonal profile, ovulation	Laparoscopic RYGB	Significant ↑ in AMH, regular menstruation resumed, ovulation improved, ↓ TESTO	Switzerl and	6 and 12 months post-op
[60] Shehata et al. (2025) Prospective cohort	79 morbid obese women	LSG: 27.4 ± 5.5 (18y-37y) RYGB: 26.6 ± 5.7 (19y-38y)	5 yr	LSG: 43.2 ± 8.2 RYGB: 46.1 ± 11.4	EWL% LSG: 63.1 ± 1.5%, RYGB: 65.2 ± 8.1%, 5th yr %EWL: 50%-103%	Pregnancy conception rates %EWL	LSG:38 RYGB:41	High conception rates post-op (primary infertility: LSG 80%, RYGB 72.7%; secondary: 100% both; pre-marriage: LSG 100%, RYGB 92.3%), min pregnancy complications, no neonatal anomalies	Egypt	5 yr

Notes: PCOS - polycystic ovary syndrome; EWL - excess weight loss; SG - sleeve gastrectomy group; LMT - lifestyle modification therapy group; MCL-Menstrual cycle length(d); FPL-Follicular phase length (d); LPL-Luteal phase length (d); VLCD-Very Low Calories Diet; yr - year.

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4.2. Female Fertility and Vertical Sleeve Gastrectomy (VSG)

4.2.1. Vertical Sleeve Gastrectomy (VSG) Mechanism

Sleeve Gastrectomy (SG), involves the removal of the greater curvature of the stomach, reducing its volume by 75-85% [64,65]; thereby limiting food intake. This procedure also removes endocrine cells that secrete ghrelin (which are located in the greater curvature of the stomach), helping to reduce appetite [65]. The weight loss, along with changes in other metabolic hormones, results in the improvement of glucose homeostasis (with a positive effect on comorbidities), thus helping to regulate diabetes by "reducing appetite" [44].

SG is the most common bariatric metabolic procedure [6], accounting for more than 60% of both total and primary procedures globally [38]. Effective and durable weight loss is the most important change after SG [39]. This treatment is, also, chosen because of its well-established safety record, effectiveness, and noticeably shorter post -operative recovery period [66].

4.2.2. VSG Effects on Polycystic Ovary Syndrome (PCOS) and Menstruation

4.2.2.1. VSG Effects on Restoration of Menstrual Cycles and Infertility

According to a prospective multi-center cohort study [39] named "Sleeve Gastrectomy for Obese Polycystic Ovary Syndrome" (SGOP), (in order to confirm the efficacy of SG in patients with PCOS and obesity) 79.03% (181/229) of patients achieved menstrual disorder restoration a year after SG with a total weight loss(TWL)% of 33.25 ± 0.46%. 60.7% (139/229) of patients, respectively, achieved regular menstrual cycles within the first and third months after SG. [229 females with obesity and PCOS; mean age: 28.68 years; mean BMI: 40.91 kg/m2 with oligo/anovulatory PCOS; all patients were followed up for one year after surgery; remission of irregular menstruation was defined as a spontaneous consecutive six month menstrual cycle (21-35 days) in one year after SG] The effect of SG on menstrual remission can be observed in the early postoperative period. According to authors opinion, this study confirmed that SG has a significant effect on menstruation remission in patients with obesity and PCOS, as well as, TWL%, should be a better index for predicting remission of irregular menstruation after SG than the endpoint BMI (Table 2).

The results of a Chinese single-center study are similar to those above (rate of 78%) and higher than another Iranian study (rate 66%) [67,68]. Another Chinese study [69] (88 PCOS obesity women with and 76 control patients aged 18-45 years were enrolled between 05/2013 and 12/2020) reported that the mean 2% excess weight loss (%EWL) and percent total weight loss(%TWL) in PCOS patients at the final follow-up was 97.52% ± 33.90% and 31.65% ± 10.31%, respectively. The percentage of monthly menstruation in PCOS patients with obesity significantly increased within six months (75.86%) and at the final follow-up (79.52%) after LSG ($P<0.05$) [69]. (The definition of restoration in the study above required a consecutive three-month menstrual cycle) [69] (Table 2). Studies have demonstrated that menstrual irregularities and long cycles are associated with an increased risk of type 2 diabetes (T2DM), gestational diabetes mellitus (GDM), and coronary heart disease [70,71].

A cross-sectional study (includes 387 Saudi women post-sleeve gastrectomy from December 2023 to May 2024) revealed that a significant number of obese women present menstrual changes after SG. Specifically, 70.5% of participants reported changes in their menstrual cycle post-surgery. A positive impact of surgery on reproductive health and the menstrual cycle due to weight loss and metabolic changes is accepted [72].

The highest proportion of women reporting postoperative menstrual cycle changes was observed in the western region (78.8%), while the lowest was in the central region (59.5%). Despite these variations, the chi-square test demonstrated no statistically significant association between region and menstrual cycle changes after surgery ($p=0.140$) [72]. (The study was limited exclusively to the tribes of Saudi Arabia)

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According to a cross-sectional study of 515 pre-menopausal women (70.3% of women underwent sleeve gastrectomy (SG) and 29.7% of obese women underwent Roux-en-Y gastric bypass) revealed that before surgical procedure 38.6% of patients reported irregular menstruation in comparison with 25.0% after then surgical procedure. The mean excess weight loss (EWL) was 74.0 ± 30.4%; a total of 82.0% of the patients achieved a 50% EWL [73] (Table 2).

Alhumaidan et al. [74], showed that menstrual irregularities were reduced from 41.9% to 36.2%, indicating the positive effect of BS;(516 Saudi women who underwent various BS procedures, of which 85.9% underwent sleeve gastrectomy (SG), experiencing a mean weight loss of 54.2 kg). Specifically, menstrual cycle regularity was observed in 26.3% and 4.9% become pregnant after surgery [74] (Table 2).

Moreover, amenorrhea was resolved in all premenopausal females after SG according to another study [75]. (The procedure started in May 2007 until December 2011, 117 total patients, 87 women, were evaluated at a two-year follow-up) The mean preoperative weight was 135.6 kg ± 23.7 kg, mean BMI 46.6 ± 6.0 kg/m2, and mean age 40.3 ± 10.7 years. At 24 months follow-up, 2 of the 12 women that were defined as infertile preoperatively had given birth to two healthy children (Table 2)

4.2.2.2. Hormonal Changes Following VSG: AMH, Androgen and Ovarian Reserve

As far as AMH is concerned, according to a prospective study, there is a final increase in its level after SG. Results of 53 obese women, (with a mean age 32.4, mean BMI 44.8 kg/m2) that underwent SG, (follow-up 3 and 6 months after surgery) showed a progressive increase of AMH levels after BS [76]. Comparing the average AMH levels in the women before SG, with mean AMH levels at 3 and 6 months follow-up (3.4 and 4.8 ng/ml), a significant increase of AMH was reported comparing baseline with 6 months value ($p<0.005$), while, there was no significant difference in comparison to baseline/3 months follow-up (Table 2).

AMH levels may transiently decrease post-VSG, likely due to metabolic changes rather than diminished ovarian reserve [77]. There is a cohort study of 75 obese patients (43 PCOS and 32 non PCOS women of reproductive age 20-35 years, with an average BMI of 43.95 kg/m2), which aimed to study the effect of AG-induced weight change on AMH levels. Preoperatively, AMH levels were significantly lower in the non-PCOS group,(mean AMH:1.77, mean BMI:45,03, mean Age:29,34; mean AMH:4.68, mean BMI:42.52, mean Age: 27.77, respectively) whereas, after 6 months of the SG there was a significant reduction of BMI and AMH levels in both groups [85]. (Non-PCOS group BMI:32.67±3.51, AMH:1.18±0.84, PCOS group BMI:30.76±2.93, AMH:3.38±1.21) (Table 2).

Wang et al. [78], examined the use of sleeve gastrectomy as a treatment for 24 female obese patients with PCOS (average weight: 99.8 kg); an additional 24 obese women (average weight: 89.7 kg) with PCOS chose to undergo lifestyle modification therapy (LMT); the LMT includes dietary, exercise, and behavioral therapies. SG resulted in a significant reduction in androgen levels (0.562 ± 0.07 to 0.31 ± 0.10 ng/mL; $P = .012$), whereas androgen changes in the LMT group were not significant ($P > .05$). Weight loss was significantly greater in the SG group (15.7 kg at 3 months; $P < .0001$) compared with the LMT group (4.1 kg at 3 months and 5.7 kg at 6 months; $P < .05$). Restoring cyclicity and ovulation occurred in 20/24 (70.8-83.3%) patients following SG within 3-6 months, compared with 6/24 (25%) in the LMT group at 3 months. Overall, SG was associated with superior weight loss, hormonal improvement, and reproductive outcomes compared with LMT in obese women with PCOS (Table 2).

4.2.3. Weight Loss and Fertility Outcomes After VSG

While the fertility rate among obese female patient following BS is increased, pregnancy within 18 months is not recommended; mainly because of the adverse consequences affecting both mother and the fetus. Weight stabilization before pregnancy considered to be essential after sleeve gastrectomy in those patients [79], so as hormonal regulation, pregnancy and live birth rates to be improved [80].

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According to a retrospective study in 2018, the presence of PCOS does not negatively affect the weight loss that follows after a SG procedure; 119 PCOS patients were compared to 119 non- PCOS control patients during 2008 -2016, with mean age for all patients 35.5 ± 10.7 and mean preoperative BMI was 41.9 ± 5.2. The PCOS group presented greater weight loss postoperatively and percent weight loss (% EWL) after 12 months, compared to non-PCOS patients. (66 vs 60%; p=0.05). 222 patients (93%) had a postoperative visit at 3 months and demonstrated an average ΔBMI of - 6.8 kg/m2 and 38.1±11.6 %EWL at 3 months. 206 patients (89%) were seen at 6 months and demonstrated an average ΔBMI of - 10.1 kg/m2 and 52.9±15.2 %EWL and 200 patients (84%) were seen at 12 months and demonstrated an average ΔBMI of -12.1 kg/m2 and 62.9 ± 21.1 %EW. This study presents that SG is effective for weight loss in obese women with coexisting PCOS (mean weight loss in the PCOS was 55.4% at 6 months and 65.8% at 12 months) and may positively affect their fertility, as it was showed that 22% of PCOS patients were successfully led to pregnancy within 12 months shortly after BS procedure (69% of which were previously nulliparous) [81] (Table 2).

A retrospective study analysis at Adıyaman Medical Faculty Training and Research Hospital General Surgery Clinic, (Turkey, May 2014 until December 2019), presents 23 morbidly obese women with BMI > 40 that underwent LSG. PCOS was present in 15/23 all of whom (65.2%), with one exception, managed to have children after surgery. BMI levels significantly decreased post-LSG compared to pre-LSG values in the present study (p=0.00001). With this BMI reduction, the conception rate after surgery was 91.3% and the live birth rate of 65.2% [80] (Table 2)

In general, Kort et al. [82] demonstrated that women who achieved a weight loss of ≥10% had markedly improved reproductive outcomes compared to those with <10% weight loss. Specifically, the ≥10% weight loss group achieved pregnancy rates of 88% versus 54%, live birth rates of 71% versus 37%, and spontaneous conception rates of 35% versus 17%, respectively. These findings underscore the importance of sufficient weight reduction in optimizing fertility outcomes following bariatric surgery.

Musella et al. [83] determined the level of fertility and live birth rate at 62.7% in infertile obese women. (110 obese women who had tried unsuccessfully to become pregnant before weight loss, 69 became pregnant afterwards). The authors reported that although pregnancy rates were higher in patients who underwent SG procedure, no difference was observed in terms of the surgical procedures' fertilization rates, and they concluded that BMI and post-surgical weight loss were decisive factors in achieving pregnancy (Table 2).

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Table 2. Clinical, hormonal and fertility outcomes of VSG bariatric surgery in women with obesity.

Ref. No	Sample size	Age (years)	Time Point	BMI (Kg/m2)	Weight Loss (kg)	Parameter	Surgical procedure	Fertility outcome	Country	Follow-Up
[83] Musella et al. (2012) Retrospective study	110 infertile obese women	~29yr (mean)	≥2.5 yrs	~44 (pre-op), 34.9±2.1 kg/m2 after SG, 35.4±.5 kg/m2 gastric bypass, 34.3±2.3 kg/m2 after adjustable gastric	Not reported	Weight-loss post-surgical BMI as pregnancy predictors	sleeve gastrectomy, gastric bypass, adjustable gastric banding	62.7% became pregnant; all led to live births	Italy	≥2.5 yrs
[75] Vage et al. (2014) Prospective cohort study	117 patients (87 morbid obese women)	40.3y±10.7y (mean)	Pre-op vs 24 months post-op	46.6±6.0 (baseline), 12 months: 30.3±5.9, 24 months: 30.6±5.6	~45kg	Obesity comorbidities (incl. amenorrhea)	LSG	100% resolution of amenorrhea (resumed menses), Amenorrhea: Pre-op 17.1%, 12 months 4.6%, 24 months 0% Infertility: Pre-op 17.1, 24 months 7.7%	Norway	24 months
[78] Wang et al. (2015)	24 (SG) vs 24 (LMT) All PCOS	25.5y (22yr-35yr range)	6 months	35.2 (29-45.7 range) Pre-op: 35.2±6.2 1 month post-op: 32.6±6.7 (reduction 2.7±0.7, EWL 0.43±0.48), 3	22.3 kg (at 6 months post-SG), Pre-op: 99.8± 22.4, 1 month post-op: 92.4 ± 23.0 3 months post-op: 84.1±21.8	Menstrual cycle & ovulation recovery	SG (vs lifestyle)	83% regained normal menses & ovulation (SG) vs 25% with lifestyle. ↓ androgen levels from 0.562-0.07 ng/mL pre-op to 0.31-0.1 ng/mL post-op. improvement in PCOS symptoms	China	6 months

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				months post-op: 29.9±6.5 (reduction 5.3±1.5, EWL 0.81±0.85), 6 months post-op: 27.8±4.9 (reduction 7.8±2.9, EWL 1.02±0.92)	6 months post-op: 77.8±16.8					
[77] Bhandari et al. (2016) Cohort study	75 (43 PCOS, 32 non-PCOS)	20yr-35yr (range), mean PCOS group mean 27.77yr non-PCOS group 29,34 yrs	6 months	43.95 kg/m² (mean pre-op) Pre-SG mean BMI: 42.52, Non-PCOS mean BMI 45,03	Not reported (≈55% EWL at 6 months)	AMH level	SG	Menstrual function normalized; AMH levels ↓ Pre-SG mean AMH 4.68, Non-PCOS mean AMH 1.77, after 6 months ↓ BMI and AMH levels in both groups, Non-PCOS group BMI: 32.67±3.51, AMH: 1.18±0.84, PCOS group BMI: 30.76±2.93, AMH: 3.38±1.21	India	6 months
[81] Dilday et al. (2019) Retrospective study	119 obese PCOS patients, 119 obese non-PCOS patients	35.5yr±10.7yr	3 months, 6 months, 12 months	Pre-op BMI 42.2 PCOS Pre-op BMI 41.5 non PCOS	Mean weight loss in **PCOS** 55.4% (6 months), 65.8% (12 months) & 66% EWL after 12 months **non-**	BMI %EWL (weight loss)	SG	22% **PCOS** patients pregnant within 12 months	USA	12 months

					PCOS patients (60%), 3 months: 93% patients - 6.8kg/m² & 38.1±11.6 %EWL, 6 months: 89% patients - 10.1kg/m² & 52.9±15.2 %EWL, 12 months: 84% patients - 12.1kg/m² & 62.9±21.1 %EWL					
[76] Pilone et al. (2019) Prospective cohort study	53 obese women	32.4yr	3 months 6 months	44.8 kg/m² (pre-op mean)	Not reported 29.5% EWL at 6 months	AMH	(LSG)	↑ AMH . Menstrual cycles regularized; dysmenorrhea resolved by 6 months.	Italy	3 and 6 months
[73] Różańska-Walędziak et al. (2020) Cross-sectional study	515 obese women (post-bariatric survey)	37.4yr±7.7yr (at survey)	1 pre-op yr vs ~3 yrs post-op	42.2±7.5 (baseline) Current BMI 29.8±6.3 BMI loss 12.4±6.3	35.3±17.9 kg (at 2 years); EWL 74.0±30.4%; 82.0% of the patients achieved 50% EWL	Menstrual irregularity & hormones	LSG (70.3%), RYGB (29.7%)	Irregular cycles 38.6% pre-op→25.0% after surgery (improved regularity)	Poland	Median 37.4 months

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[67] Hu et al. (2022) Prospective non randomized trial	90 obese women (81 completed; 41 SG vs 40 med)	~28 (range 18-40)	Pre-op vs 12 months post-op	BMI ≥ 27.5 kg/m² Median BMI at endpoint 30.1 kg/m² in the drug group and 23.7 kg/m² in the surgical group	~34 kg (mean loss)	PCOS remission (cycles + pregnancy)	Sleeve Gastrectomyr (LSG)	78% PCOS complete remission after SG (vs 15% with meds) Nearly 95% endpoint BMI below the cutoff values achieved complete remission.	China	12 months
[69] Cai et al. (2023) Prospective study	88 PCOS vs 76 control obese women	18-45 yrs (28.7 yrs median)	Pre-op vs 6 months post-op	37.4 (median baseline PCOS)	Not reported EWL 97.52±33.90% TWL 31.65±10.31%	Menstrual recovery (regular cycles) Increased risk of T2DM, GDM	Sleeve Gastrectomy (LSG)	75.86% regained regular cycles by 6 months (from ~0% pre) Final follow up 79.52% after LSG	China	Mean 3.23 yrs
[80] Öner et al. (2023) Retrospective analysis	23 morbidly obese women	31.3yr±5.1yr (mean)	12months (1year)	45.04±3.43 (pre-op mean) 28.65±3.14 (12 months post-op)	Not reported	LH, FSH, PRL, E2, TESTO levels, time to pregnancy	Sleeve gastrectomy (LSG)	91.3% conceived; 71.42% gave birth after LSG, 28.58% aborted, 65.21% live birth rate, 82.6% women in IVF prior to LSG, 57.89% had children after LSG, 66.67% natural conception after surgery, 13.33% both NC and IVF, 20% following IVF only	Turkey	5 yrs

[68] Alamdari et al. (2024) Single-center study	50 obese PCOS women	31.69 yr ± 9.54yr	A yr post-op	Mean BMI before surgery 44.28±3.03kg/m^2, Mean BMI after surgery 29.37±2.41kg/m^2		PCOS (Clinical signs, symptoms, hormonal assessments)	VSG	Oligomenorrhea improved 66% (of patients.), PCOS improved 74% (of patients), Mean FSH, testo, DHEAs improved (in all patients), ↓ LH, ↓ LH/ FSH ratio, ↓ estrogen noted in patients with improved clinical response	Iran	1 yr
[74] Alhumaidan et al. (2024) Online survey	516 obese women	18y-50yr (37.2% age 18yr-30yr)	Pre- vs post-surgery (self-reported)	Not reported	54.2 kg (mean lost)	PCOS (12.4%), hormonal imbalances (2.5%), Menstrual abnormalities, co-morbidities (1.6%)	85.9% SG + various BS	Menstrual irregularities from 41.9% to 36.2%, Menstrual cycle regularity 26.3%, 4.9% pregnant, no change in cycle frequency (10.6 cycles/yr); slight decrease in flow/duration	Saudi Arabia	Varied (~0-2 yrs post-op)
[72] Alsareii et al. (2024) Cross-sectional study	387 post-LSG women	~34 y (18y-55y range)	Post-surgery survey (varied times)	Not reported	Not reported (87% lost weight)	Menstrual changes (cycle regularity)	SG	70.5% (n=273) menstrual changes, 26.3% (n=102), regular cycles (post-op) vs 62.5% pre-op; 4.9% pregnant.	Saudi Arabia	1 to 12+ months post-op

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[39] Zhao et al. (2024) Prospective multicenter cohort study	229 women with obesity + PCOS	28.68±0.4 (mean)	Pre-op vs 1yr post-op	40.91kg/m² (mean BMI)	Not reported TWL 33.25±0.46% TWL% 1 month 12.27±0.21% TWL% 3 months 21.90±0.33% TWL% 6 months 29.46±0.40% TWL% 12 months 33.25±0.46%	Menstrual irregularity (PCOS)	Sleeve Gastrectomy (SG)	79.03% regained regular menstruation, 21-35 days menstrual cycle after SG, 31.0% regular menstrual cycles in the first month after SG, 60.7% achieved regular menstrual cycles the third month after SG	China	1 year

Notes: PCOS - polycystic ovary syndrome; EWL - excess weight loss; LSG – Laparoscopic Sleeve Gastrectomy, SG - sleeve gastrectomy group; LMT - lifestyle modification therapy group. All fertility outcomes refer to post-surgery results in the respective study populations, AMH -Anti-Müllerian hormone, yr - year.

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5. Molecular Mechanisms Known So Far to Be Involved in Female Fertility Improvement After Weight Loss Following Bariatric Surgery (RYGB, VSG)

Studies demonstrate that both Sleeve Gastrectomy (SG) and Roux-en-Y Gastric Bypass (RYGB) induce marked loss of visceral fat (VAT) within the first few months with the reduction ranging from 35%-55% after 6-12 months postoperatively. While Total Weight Loss (TWL) ranging, approximately, 20%-35%, respectively, [Whole-body magnetic resonance imaging (MRI) provides accurate evaluation of surgical procedures' effect on individual patients' tissue composition], [97,98,105].

The degree of surgical-induced weight loss and the loss of VAT contribute significantly to endocrine changes in obese female patients, including improvements in the regularity of menstrual cycle, ovulatory function, and overall reproductive outcomes aside from their metabolic benefits [14]. Some studies report declines in Anti Mullerian Hormone (AMH) postoperatively, while others suggest stabilization or improvement in functional ovarian reserve; from a clinical perspective, it is important to underline that AMH is the most accurate hormonal marker of ovarian reserve, informs about the number of oocytes present in the ovaries of women at a specific moment of their life and the capacity of ovarian response to IVF treatment [47,50,51,76,77]. This observed reduction in AMH does not mean oocyte reduction. Instead, this reduction likely reflects a possible improvement in hyperandrogenism and insulin resistance, thus leading to a reduction in the recruitment of small, immature follicles, a characteristic mainly observed in women with polycystic ovary syndrome (PCOS), rather than an actual reduction in ovarian reserve [99,100]. Additionally, reduced insulin resistance, as well as androgen levels, result in normalization of LH secretion and restoration of a normal LH/FSH ratio, changes that are closely linked to improved ovulatory function [101]. This reduction alleviates insulin-mediated amplification of LH driven ovarian androgen synthesis and improves hypothalamic gonadotropin releasing hormone's (GnRH) pulsatility; restoring the balanced gonadotropin release [101,102]

Loss of VAT is associated with an increase of sex hormone binding globulin (SHBG), due to relief of insulin-mediated suppression of SHBG synthesis in the liver, leading to a reduction in circulating free testosterone and androgens' levels; while total testosterone levels often decrease or remain stable, free testosterone levels decline, reflecting the role of SHBG in restoring hormonal balance after weight loss [103,104]. Additionally, bariatric surgery(BS) is associated with significant reductions in circulating adrenal and ovarian androgens, including dehydroepiandrosterone sulfate (DHEAS) and androstenedione, particularly in women with PCOS, driven by improvements in insulin sensitivity , improved hirsutism scores and reduction in obesity-related inflammation [103,104].

Low-grade chronic inflammation in adipose tissue contributes to the circulation of inflammatory markers and for this reason BS follow-up studies frequently apply measurements of markers such as C-Reactive Protein (CRP), Tumor Necrosis Factor α (TNF-alpha) and/or Interleukin 6 (IL-6). IL-6 is mostly reported to decrease after the surgical procedure. CRP originates primarily from the liver. Still, it is considered a marker of adipose inflammation as the liver is highly affected by obesity and CRP has consistently been shown to be up regulated with obesity. After BS, CRP levels show rapid declines that persist for up to 10 years, postoperatively [105].

The endocrine function of the adipose tissue is carried out by the secretion of different proteins called adipokines into the circulation. These include leptin, which suppresses appetite when lipid storage is high and stimulates pro-inflammatory immune response and adiponectin (APN), that acts on other organs such as the liver and muscle, also, plays an anti-inflammatory role and promotes insulin sensitivity by increasing fatty acid oxidation, thus regulating lipoprotein metabolism and inhibiting hepatic glucose production [106]. The notable reduction in VAT, (following SG or/and RYGB), leads to a significant reduction in circulating leptin levels, reflecting improved leptin sensitivity and contributing to the restoration of Hypothalamic Pituitary Ovarian (HPO) axis' function. Increase in the adiponectin levels was also more significant after the RYGB in comparison to the SG. The changes in leptin and adiponectin levels after the RYGB surgery might be due to the fact that weight loss and other metabolic changes are regulated by intestinal hormones. [113,114].

Weight loss after BS is effective in lowering CRP and increasing adiponectin levels in PCOS women; this improvement was slower compared to obese non PCOS patients, a genetic predisposition to insulin resistance might explain these findings [106,112].

Beyond adipose-secreted adipokines, RYGB and SG, also, induces changes in gastrointestinal hormones that regulate appetite, glucose metabolism, and insulin sensitivity, thus enhancing the metabolic-hormonal improvements that support the female reproductive axis. A great variety of hormones secreted from the gastrointestinal tract communicate with peripheral tissues and the central nervous system to regulate glucose homeostasis. In this report, the hormones of interest are Peptide YY (PYY), Glucagon-like Peptide-1 (GLP-1), and Ghrelin. SG is associated with sustained suppression of ghrelin, due to gastric fundus resection, whereas ghrelin levels tend to normalize or increase after RYGB. In contrast, both SG and RYGB induce substantial postprandial increase in GLP-1 and PYY levels, driven by accelerated nutrient delivery to the distal intestine (compared with preoperative levels or weight loss induced by diet) [107–111]. Ghrelin is a 28-amino acid secreted in the stomach, promotes the release of growth hormone (GH), associated with hunger signaling and decrease insulin secretion. PYY and GLP-1 are secreted by distal intestinal L cells to decrease appetite, increase satiety, and slow gut motility; PYY improves insulin sensitivity and GLP-1 functions as an incretin to enhance glucose-stimulated insulin release [110]

The aforementioned endocrine changes in obese female patients resulting from the Bariatric surgical mechanism, lead to sustained reductions in adipose tissue and insulin resistance indirectly, improving female fertility. While adipose tissue gradually decreases, [obesity-related endocrine disorders, including low-grade chronic inflammation, leptin resistance and hyperinsulinemia, all of which, adversely, affect the HPO axis] circulating leptin levels are normalized and inflammatory markers are reduced, contributing to the restoration of HPO axis' function [113,114]. Suppression of ghrelin combined with the postprandial secretion of GLP-1 and PYY, shifts hypothalamic signaling toward increased satiety, reduced energy intake, and improved glucose-dependent insulin action, thereby promoting negative energy balance and loss of visceral adipose tissue; the increase in PYY may also contribute to improved insulin sensitivity [111]. Although GLP-1 and PYY exert a potent effect on hypothalamic appetite-regulating system and on energy homeostasis, current evidence does not support a direct action on GnRH neurons and GnRH pulsatility in humans and still remains under investigation. For example, data from rodent models suggest gut hormones may have direct stimulatory effects on reproductive hormone release. However, the effects of gut hormones on reproductive function in humans are more complex, with involvement of direct (e.g. via gut hormone receptor agonism) as well as indirect (e.g. via weight reduction in people with obesity) mechanisms[115]. Additionally, the role of GLP-1 on GnRH secretion was investigated in ovariectomised (OVX) ewes, in which GnRH and luteinising hormone (LH) secretion had been restrained by treatment with estrogen and progesterone[116]. In conclusion, these endocrine changes, as well as the gastrointestinal hormones of energy homeostasis changes highlight the potential role of the gut-brain axis on adipose tissue supporting improved ovulatory function and fertility markers in obese women following BS.

6. Pregnancy Recommendations Following Bariatric Surgery

The American College of Obstetricians and Gynecologists (ACOG), The Obesity Society (TOS), and the American Association of Clinical Endocrinology (AACE) recommend postponing conception for 12 to 24 months after bariatric surgery (BS) [84]. This interval allows women to achieve maximum and stable postoperative weight loss and reduces the risk of nutritional deficiencies and potential adverse effects on fetal development during the period of rapid catabolism, which typically lasts 6 to 18 months post-surgery [35].

In selected cases, such as advanced maternal age or diminished ovarian reserve, a shorter interval before pregnancy may be considered; however, this decision must balance the potential benefits of earlier conception against the risks associated with nutritional deficits and residual obesity-related comorbidities [85].

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7. Results & Discussion

The present study evaluates the impact of vertical sleeve gastrectomy (VSG) and Roux-en-Y gastric bypass (RYGB)on fertility outcomes in women with obesity-related infertility. Obesity is associated with menstrual irregularities, anovulation, and diminished ovarian reserve [22,23]. For those patients who fail to achieve results with pharmacological treatments and lifestyle changes, bariatric surgery is a significant therapeutic option. These surgical interventions result in noteworthy improvements in the regularity of menstrual cycle, ovulatory function, and overall reproductive outcomes aside from their metabolic benefits [14].

VSG is one of the most widely used bariatric techniques with significant postoperative benefits in weight management, menstrual cycle restoration, and improved fertility outcomes. Evidence indicates that weight loss after SG, contributes significantly to improvement in hormonal profile, including reductions in androgen and anti-Müllerian hormone (AMH) levels, even in women with polycystic ovary syndrome (PCOS). This aligns with findings reported that both SG and RYGB reduced hyperandrogenism and improved ovulatory function [39,60,69,78]. A particularly important finding is that improvement in menstrual disorders is observed as early as the first months after surgery, an element that highlights the direct effect of weight loss on female reproductive function [39].

RYGB, also, demonstrates significant efficacy in improving reproductive health parameters, especially in women with severe obesity and menstrual disorders; with studies suggesting higher rates in RYGB recipients compared to VSG, possibly due to greater metabolic correction [60,61]. It is confirmed that laparoscopic RYGB (LRYGB) results in a substantial excess weight loss and reductions in testosterone levels at 6 and 12 months, thereby improving the metabolic and hormonal profile of women with PCOS [51]. Surgical weight loss following RYGB has been associated with improvement in PCOS manifestations, while postoperative conception rate reaches 100% among infertile morbidly obese women with PCOS, who desire pregnancy [58]. While RYGB is effective in promoting substantial weight loss and improving reproductive and metabolic parameters in obese women with PCOS, (including reductions in hyperandrogenism, normalization of menstrual cyclicity, and higher rates of spontaneous conception) the precise impact of this procedure on ovarian reserve markers, such as AMH, remains incompletely understood [48,50].

A comparative evaluation of the two surgical techniques, SG and RYGB, highlights both common and differentiated benefits in terms of improving reproductive function. Over at least a 5 years period, SG and RYGB cause considerable and continuous weight reduction and effective control of obesity-related comorbidities [45]. Although both techniques contribute to restoring the menstrual cycle and increasing conception rates, [58,73,74], SG seems to have a faster effect on cycle regulation and reducing androgen levels, especially in patients with PCOS [39,78]. On the other hand, RYGB is associated with significant postoperative changes in ovulation and fertility improvement, particularly in women with severe obesity [60,61,86]. While RYGB is connected with more obvious metabolic improvements, micronutrient deficiencies and the occurrence of small-for-gestational-age (SGA) births are often observed. On the other hand, VSG offers a safer nutritional profile with lower, but still significant weight loss [60,87,88]. In conclusion, the choice of surgical method should be individualized, taking into account the patient's profile, concomitant endocrine disorders, and reproductive goals.

The time elapsed from BS to conception is another critical aspect: the first 12-24 months after surgery are characterized by fast weight loss and nutritional swings that can negatively impact maternal and fetal health and the outcomes of IVF treatment. For this reason, most specialized societies recommend avoiding pregnancy - including ART - for at least 12-18 months after VSG or RYGB, giving time for the patient's weight and nutritional status to stabilize [89]. On the other hand, delayed pregnancy, especially in cases of advanced reproductive age among women, may lead to reduced fertility because of the decline in oocytes quality with increasing age [50,89]. Therefore, patients should receive comprehensive counseling from their surgeon and reproductive specialist regarding the potential impact of delayed conception on fertility potential and be offered individualized treatment plans that balance the benefits of weight-loss with the risks associated with advanced maternal age. The definition of an optimal time to conceive after BS remains undefined due to the limited evidence.

Beyond timing of conception, another post-surgery factor to consider is long-term weight maintenance, since weight regain can influence metabolic health, fertility and IVF outcomes. Weight regain could occur 2-3 years postoperatively (approximately 5-10% of lost weight), and a significant rebound (10-25%) may occur by 5-10 years, particularly after VSG [88]. Long term beyond 7-10 years, a great number of patients may develop significant weight regain, reaching up to 25-30% of the initially reduced body weight [90–94]. In patients undergoing VSG, evidence indicates that approximately 15-25% of individuals regain at least 10% of their lowest postoperative body weight within 5 years. In contrast, after RYGB, weight regain appears somewhat less frequent; however, between 10-20% of patients experience weight recovery exceeding 20% of their total weight loss within 5-7 years. Furthermore, large cohort studies and meta-analyses consistently report that 20-35% of patients develop clinically significant weight regain, typically defined as regaining more than 25% of the initially lost weight, within 5-10 years postoperatively [93,94]. In addition, weight regain has been associated with recurrence of anovulation and metabolic disturbances, thereby reducing fertility benefits previously achieved. Notably, RYGB appears to confer more durable weight loss and metabolic improvement than VSG but carries a higher risk of nutritional deficiencies, which may negatively impact fertility and pregnancy outcomes if not carefully managed [87].

Maternal mortality, is a condition rarely documented. The available population-based evidence shows that BS does not pose a threat to maternal mortality but rather decreases it in high-risk obese patients [60]. The absolute maternal risk of mortality after such surgeries remains extremely low <0.1%, (fewer than 1 per 1,000 births) [88,95]. However, close monitoring before and during pregnancy-related BS, is essential in order to avoid obstetric complications. It has to be recognized that very few studies have isolated the maternal mortality risk following BS with most research focused on serious maternal morbidity, overall morbidity, perinatal, or infant mortality. The findings are to be considered with a certain degree of reservations owing to confounding factors.

VSG and RYGB are highly effective bariatric procedures in order to achieve considerable weight loss and improve fertility, leading to improved gestational outcomes in overweight, obese women. The best reproductive results require proper preconception control and careful postoperative dietary supervision in order to ensure the health of the mother and fetus as well. The following Table 3 summarizes data related to clinical, hormonal and fertility outcomes of VSG vs RYGB in obese women with and without PCOS; collected from studies referred to aforementioned fields; organized and unified in a table format aiming for immediate understanding of the available evidence.

Table 3. Comparison of VSG vs RYGB in obese women of reproductive age.

Parameter	SG (Sleeve Gastrectomy)	RYGB (Roux-en-Y Gastric Bypass)	References
Clinical Guidance for Women Planning Pregnancy	Lower nutritional risk; preferred in women with prioritizing pregnancy.	Requires more intensive nutritional monitoring; preferred in women with severe obesity or metabolic comorbidity (e.g., T2DM)	ASMBS Guidelines; Shehata N, et al. Obes. Surg. 2025 [60]
Weight Loss Metabolic Outcomes	Effective & sustained weight loss; somewhat less than RYGB in long-term studies. Improves insulin sensitivity and metabolic profile.	Greater and more durable weight loss compared with VSG. Stronger metabolic effect, especially in T2DM and severe obesity.	Johansson K, et al. N Engl J Med. 2015[87] Akhter Z, et al. PLoS Med. 2019 [88]

Fertility Outcomes (Ovulation, Menstrual Cycles, PCOS)	Improved menstrual regularity, restoration of ovulation, reduced hyperandrogenism. Improving fertility in PCOS obese women.	Similar or stronger effect on ovulation and fertility improvement, particularly in women with severe obesity	Goldman 2016[86] Shehata N, et al. Obes. Surg. 2025 [60]
Spontaneous Conception Rates	Increased spontaneous conception rates after weight loss. Limited long-term comparative data.	Increased conception rates, sometimes higher than SG in observational studies.	Shehata N, et al Obes. Surg.2025 [60]
Assisted Reproduction Outcomes (IVF)	Higher ovarian response rates, improved oocyte quality after weight loss, enhanced endometrial receptivity, ART positive results	Similar benefits; however, micro-nutrient status may affect ART outcomes.	Goldman RH, et al. Obes. Surg2016[86] Rittenberg V, et al. Reprod Bio med Online.2011 [96]

Limitations of this study include the assessment of only two bariatric procedures RYGB and SG. The recommendations presented are based on a systematic research of the available literature. Despite the expanding evidence that BS improves female fertility in women with morbid obesity, there are significant questions about the underlying biological mechanisms and the long-term reproductive outcomes. Also, the optimal bariatric surgery-to-conception interval, particularly in relation to ovarian reserve markers, and maternal age still remains under discussion. Moreover, research is inadequate to define specific procedure to avoid weight regain (post-surgery factor to consider is long-term weight maintenance), since weight regain can influence metabolic health, fertility and IVF outcomes. Finally, the impact of BS on long term outcomes regarding female fertility remains under investigation. Addressing these gaps that come from the studies decision-making is necessary to refine individualized surgical procedure in order to optimize maternal outcomes.

8. Conclusions

It has been established that both VSG and RYGB seem to improve fertility outcomes in women with obesity-related infertility. Beyond weight reduction, these benefits appear to be mediated by complex molecular and endocrine mechanisms, including restoration of hypothalamic–pituitary–ovarian axis function (menstrual regularity), improvements in insulin resistance, reducing chronic inflammation and increased pregnancy rates. Choice of surgical procedure should be individualized according to reproductive goals, metabolic risk and capacity for nutritional follow up. Despite growing clinical evidence, comparative data on the molecular and endocrine effects of VSG versus RYGB on ovarian reserve, follicular development, and long-term reproductive outcomes remain limited. Large, prospective and multicenter trials comparing VSG and RYGB on standardized reproductive outcomes are needed to determine the optimal surgical approach. Such studies should, also, clarify the ideal time to conception postoperatively and address long-term reproductive endocrine changes, in order to set evidence-based guidelines for fertility management in obese women followed bariatric surgery.

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Abbreviations

The following abbreviations are used in this manuscript:

AACE	The American Association of Clinical Endocrinology
ACOG	The American Congress of Obstetricians and Gynecologists
AMH	Anti-Mullerian Hormone
ART	Assisted Reproductive Technology
ASMBS	The American Society for Metabolic and Bariatric Surgery
ASRM	The American Society of Reproductive Medicine Committee
BL	Base Line
BR	Birth Rate
BS	Bariatric Surgery, often called MBS: Metabolic and Bariatric Surgery
BMI	Body Mass Index
BSCI	Bariatric Surgery to Conceptional Interval
CHD	Coronary Heart Disease
CVD	Cardiovascular Disease
DHEA	Dehydroepiandrosterone sulfate
ΔBMI	"Change" in Body Mass Index
EWL	Excess Weight Loss
FAI	Free Androgen Index
FSH	Follicle-Stimulating Hormone
GDM	Gestational Diabetes Mellitus
GNRH	Gonadotrophin-Releasing Hormone
HPO axis	Hypothalamic-Pituitary-Ovarian axis
IFSO	The International Federation for the Surgery of Obesity and Metabolic Disorders
IR	Insulin Resistance
IUD	Intra-Uterine Device
IVF	In Vitro Fertilization
LARC	Long-Acting Reversible Contraception
LBW	Low Birth Weight
LGA	Large-for-gestational-age
LH	Luteinizing Hormone
LMT	Lifestyle modification therapy
MCI	Menstrual Cycle Irregularities
NC	Natural Conception
NICE	National Institute for Health and Clinical Excellence
OR	Odds Ratio
OCPs	Oral Contraceptive Pills
PCOS	Polycystic Ovarian Syndrome
RYGB	Roux-en-Y Gastric Bypass, often called LYRGB (Laparoscopic RYGB)
SG	Sleeve Gastrectomy, often called LSG (Laparoscopic SG) or VSG (Vertical Sleeve Gastrectomy)
SGA	Small for Gestational Age
SHBG	Sex Hormone-Binding Globulin
T2DM	Type 2 Diabetes Mellitus
TOS	The Obesity Society
TWL	Total Weight Loss
VLCD	Very Low Calories Diet
WHO	World Health Organization

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