

Impact of Sleeve Gastrectomy on Obesity Indices, Reproductive Hormones, and Follicular Quality: A 12-Month Prospective Study

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Abstract

Obesity impairs reproductive health through hormonal imbalances and insulin resistance. This prospective study evaluated the effects of laparoscopic sleeve gastrectomy on obesity indices, reproductive hormones, and ovarian reserve in 32 morbidly obese women over 12 months. Assessments at baseline, 6, and 12 months measured BMI, anti-Müllerian hormone (AMH), antral follicle count (AFC), follicle-stimulating hormone (FSH), luteinizing hormone (LH), sex hormone-binding globulin (SHBG), estradiol, free testosterone, and HOMA-IR. BMI decreased from 42.12 (± 0.45) to 25.65 (± 0.34), AMH from 3.0 to 2.0 ng/mL, and AFC from 11 to 6–7 per ovary (all $p < 0.001$). Concurrently, SHBG increased (36 to 64 nmol/L), free testosterone decreased (29 to 9 ng/dL), and HOMA-IR improved from 3.8 (± 0.9) to 1.2 (± 0.3) ($p < 0.001$). Despite reduced AMH and AFC, enhanced hormonal profiles and insulin sensitivity suggest improved follicular quality, indicating normalized ovarian function and reproductive potential post-surgery. Sleeve gastrectomy thus offers metabolic and reproductive benefits, prioritizing follicle quality over quantity, with implications for fertility management in obese women.

1. Introduction

Obesity disrupts reproductive health by altering ovarian function through hormonal imbalances—elevated androgens, reduced SHBG—and metabolic disturbances like insulin resistance and chronic inflammation [1, 2]. These changes impair ovulation, oocyte quality, and fertility, particularly in morbidly obese women (BMI > 40 kg/m²) [3]. Sleeve gastrectomy, a cornerstone of bariatric surgery, promotes substantial weight loss and metabolic improvement, potentially restoring hormonal balance and reproductive function [4, 5]. However, its effects on ovarian reserve markers, such as AMH and AFC, remain debated. While AMH reductions post-surgery are documented [6], their implications—diminished fertility or physiological normalization—require clarification. We hypothesized that sleeve gastrectomy enhances follicular quality despite AMH and AFC declines, driven by improved hormonal and metabolic profiles. This 12-month prospective study investigates these changes in 32 morbidly obese women, exploring the interplay between weight loss, reproductive hormones, and ovarian function.

2. Materials and Methods

2.1 Study Design

This prospective observational study enrolled 32 morbidly obese women undergoing laparoscopic sleeve gastrectomy at Hippokration General Hospital, Athens, from January 2021 to February 2022.

2.2 Participants

Inclusion criteria included women aged 18–50 years with BMI > 40 kg/m², no menopause history, and consent to participate. Exclusion criteria comprised polycystic ovary syndrome (PCOS), recent reproductive surgery (past 6 months), or medications affecting fertility.

2.3 Assessments

Data were collected at baseline (pre-surgery), 6 months, and 12 months post-surgery:

- **Hormonal Analysis:** Blood samples, drawn during the follicular phase (days 2–5), measured AMH (ELISA, Beckman Coulter, sensitivity 0.08 ng/mL), FSH, LH, SHBG, estradiol, and free testosterone (chemiluminescent immunoassays, Roche Diagnostics). Insulin resistance was assessed via HOMA-IR: $[\text{insulin } (\mu\text{U/L}) \times \text{glucose } (\text{mg/dL})] / 405$.
- **Ovarian Function:** See Section 2.4 for transvaginal ultrasound details.
- **BMI:** Calculated as $\text{weight } (\text{kg}) / \text{height } (\text{m}^2)$.

2.4 Transvaginal Ultrasound Monitoring

Ovarian function was assessed using transvaginal ultrasound (TVUS) with a GE Voluson E8 system (6–9 MHz probe). Scans were performed by a single experienced ultrasonographer during the early follicular phase (days 2–5) to count antral follicles (2–10 mm diameter) in both ovaries. Three scans were conducted per participant: pre-surgery (baseline), 6 months post-surgery, and 12 months post-surgery. Each session lasted approximately 15 minutes, with patients in the lithotomy position. AFC was recorded as the sum of follicles per ovary, ensuring consistency across time points. The procedure adhered to standard gynecological ultrasound protocols, with minimal discomfort reported. Ethical oversight ensured participant safety and data confidentiality, with ultrasound findings anonymized and stored securely.

2.5 Statistical Analysis

Data were analyzed using SPSS v.27. Descriptive statistics (mean $\pm$ SD) summarized baseline and follow-up measures. Due to non-normal distributions (Shapiro-Wilk test, $p < 0.05$), Wilcoxon signed-rank tests assessed paired differences, and Spearman correlations evaluated associations. Significance was set at $p < 0.05$ (two-sided).

3. Results

3.1 Baseline Characteristics

Participants ($n = 32$) had a mean age of $33.0 (\pm 4.0)$ years and BMI of $42.12 (\pm 0.45)$ kg/m². Baseline reproductive parameters included AMH (3.0 ± 0.0 ng/mL), AFC (11.0 ± 2.0 right, 11.0 ± 1.0 left), FSH (6.0 ± 1.0 mIU/mL), LH (7.0 ± 1.0 mIU/mL), SHBG (36.0 ± 7.0 nmol/L), estradiol (31.0 ± 4.0 pg/mL), free testosterone (29.0 ± 9.0 ng/dL), and HOMA-IR (3.8 ± 0.9) (Table 1).

Table 1
Baseline Characteristics of 32 Morbidly Obese Women

Parameter	Mean	SD
Age (years)	33.0	4.0
BMI (kg/m ²)	42.12	0.45
AMH (ng/mL)	3.0	0.0
AFC—Right Ovary	11.0	2.0
AFC—Left Ovary	11.0	1.0
FSH (mIU/mL)	6.0	1.0
LH (mIU/mL)	7.0	1.0
SHBG (nmol/L)	36.0	7.0
Estradiol (pg/mL)	31.0	4.0
Free Testosterone (ng/dL)	29.0	9.0
HOMA-IR	3.8	0.9

Table 2
Changes in Parameters at 6 Months Post-Sleeve Gastrectomy

Parameter	Baseline (Mean ± SD)	6 Months (Mean ± SD)	Difference (Mean ± SD)	P-value
BMI (kg/m ²)	42.12 ± 0.45	32.87 ± 1.01	-9.24 ± 0.91	< 0.001
AMH (ng/mL)	3.0 ± 0.2	2.5 ± 0.3	-0.62 ± 0.25	< 0.001
AFC—Right Ovary	11.0 ± 2.0	9.0 ± 1.0	-2.63 ± 1.66	< 0.001
AFC—Left Ovary	11.0 ± 1.0	8.0 ± 1.0	-3.03 ± 1.47	< 0.001

Table 3
Changes in Parameters at 12 Months Post-Sleeve Gastrectomy

Parameter	Baseline (Mean $\pm$ SD)	12 Months (Mean $\pm$ SD)	Difference (Mean $\pm$ SD)	P-value
BMI (kg/m ²)	42.12 $\pm$ 0.45	25.65 $\pm$ 0.34	-16.47 $\pm$ 0.66	< 0.001
AMH (ng/mL)	3.0 $\pm$ 0.2	2.0 $\pm$ 0.2	-0.92 $\pm$ 0.30	< 0.001
AFC—Right Ovary	11.0 $\pm$ 2.0	7.0 $\pm$ 1.0	-4.31 $\pm$ 2.01	< 0.001
AFC—Left Ovary	11.0 $\pm$ 1.0	6.0 $\pm$ 1.0	-4.88 $\pm$ 1.52	< 0.001
FSH (mIU/mL)	6.0 $\pm$ 1.0	9.0 $\pm$ 1.0	+ 2.83 $\pm$ 1.03	< 0.001
LH (mIU/mL)	7.0 $\pm$ 1.0	9.0 $\pm$ 1.0	+ 2.04 $\pm$ 1.46	< 0.001
SHBG (nmol/L)	36.0 $\pm$ 7.0	64.0 $\pm$ 12.0	+ 27.51 $\pm$ 8.72	< 0.001
Estradiol (pg/mL)	31.0 $\pm$ 4.0	49.0 $\pm$ 4.0	+ 18.16 $\pm$ 4.75	< 0.001
Free Testosterone (ng/dL)	29.0 $\pm$ 9.0	9.0 $\pm$ 2.0	-19.35 $\pm$ 8.70	< 0.001
HOMA-IR	3.8 $\pm$ 0.9	1.2 $\pm$ 0.3	-2.60 $\pm$ 0.78	< 0.001

3.2 Post-Surgery Changes

At 6 months, BMI decreased to 32.87 ($\pm$ 1.01) kg/m², AMH to 2.5 ($\pm$ 0.3) ng/mL, and AFC to 9.0 ($\pm$ 1.0) and 8.0 ($\pm$ 1.0) for right and left ovaries, respectively (all p < 0.001, Table 2). By 12 months, BMI fell to 25.65 ($\pm$ 0.34) kg/m², AMH to 2.0 ($\pm$ 0.2) ng/mL, and AFC to 7.0 ($\pm$ 1.0) and 6.0 ($\pm$ 1.0) (p < 0.001). Hormonal shifts included FSH rising to 9.0 ($\pm$ 1.0) mIU/mL, LH to 9.0 ($\pm$ 1.0) mIU/mL, SHBG to 64.0 ($\pm$ 12.0) nmol/L, estradiol to 49.0 ($\pm$ 4.0) pg/mL, free testosterone dropping to 9.0 ($\pm$ 2.0) ng/dL, and HOMA-IR improving to 1.2 ($\pm$ 0.3) (p < 0.001, Table 3). Trends are visualized in Fig. 1.

3.3 Correlations

HOMA-IR negatively correlated with SHBG (r = -0.45, p = 0.01) and positively with free testosterone (r = 0.55, p = 0.004), while AMH and AFC showed a strong positive association (r = 0.65, p = 0.001) at 12 months (Fig. 2). Hormonal and metabolic improvements are summarized in Fig. 3.

4. Discussion

The reductions in AMH and AFC post-sleeve gastrectomy, alongside hormonal restoration, suggest a normalization of ovarian function rather than diminished fertility. Our study revealed an apparent paradox: while hormonal profiles improved, AMH and AFC decreased. However, a closer analysis of the data and existing literature indicates that these changes are not necessarily linked to negative reproductive outcomes.

4.1 Controversial Findings on AMH and Weight Loss

AMH serves as a marker of ovarian reserve, produced by granulosa cells of developing follicles. In most studies, AMH correlates directly with antral follicle count (AFC) and typically reflects the number of available follicles in the ovaries [26]. In patients with polycystic ovary syndrome (PCOS), AMH levels are often elevated due to an increased number of small follicles [8]. Regarding weight loss following bariatric surgery, the data are conflicting. Some studies report a decrease in AMH post-surgery, potentially due to a reduction in overall ovarian mass and the number of small follicles, particularly in women with PCOS who initially exhibit elevated AMH levels [6, 7]. This reduction may result from the gradual normalization of ovarian function and the elimination of excessive folliculogenesis commonly observed in PCOS [26]. Conversely, other studies suggest AMH may increase post-bariatric surgery, reflecting individual variability or different surgical impacts [9]. Our findings align with the former, showing a consistent AMH decline (3.0 to 2.0 ng/mL) alongside AFC reductions, suggesting a quantitative shift in ovarian dynamics.

4.2 Follicular Quality

Despite the decline in AMH levels and follicle count, hormonal changes—such as the restoration of FSH (6.0 to 9.0 mIU/mL), LH (7.0 to 9.0 mIU/mL), and SHBG (36.0 to 64.0 nmol/L)—may indicate a qualitative improvement in follicles [10]. Enhanced hormonal profiles likely contribute to better overall ovarian function and the development of higher-quality follicles, as weight loss is often accompanied by improvements in metabolic health and insulin sensitivity [13]. The higher quality of remaining follicles could imply improved oocyte maturation and enhanced reproductive prospects, even with a reduced follicle count. Specifically, the observed increase in SHBG and decrease in free testosterone (29.0 to 9.0 ng/dL) post-surgery suggest significantly improved hormonal conditions, creating a more favorable environment for the development of better follicles and potentially superior reproductive outcomes [11]. These findings are consistent with reports that weight loss mitigates hyperandrogenism, a key barrier to ovulation [15].

4.3 Metabolic Health and Fertility

Another key finding is the direct link between metabolic health and reproductive function. Bariatric surgery markedly improves metabolic function, reducing insulin resistance (HOMA-IR from 3.8 to 1.2) and associated endocrine disturbances tied to obesity [14]. These metabolic improvements are well-documented to support the restoration of ovulation and enhance fertility, even in women without PCOS [12]. As noted elsewhere, despite AMH reductions post-weight loss, women undergoing bariatric surgery

often exhibit overall improvements in reproductive health, reinforcing the idea that follicle and oocyte quality improve [27]. The strong negative correlation between HOMA-IR and SHBG ($r=-0.45$, $p = 0.01$) and positive correlation with free testosterone ($r = 0.55$, $p = 0.004$) underscore how metabolic correction drives hormonal normalization.

4.4 Quality as a Critical Factor

The enhancement of the hormonal profile post-surgery is a pivotal finding. Increased FSH, LH, and SHBG, alongside reduced free testosterone, contribute to better follicular quality [10]. Studies demonstrate that follicles remaining after surgery are often of superior quality, despite their reduced number, due to more favorable hormonal conditions for normal oocyte development and maturation [13]. Furthermore, the reduction in free testosterone and rise in SHBG alleviate hyperandrogenism, which frequently hinders ovulation, resulting in follicles with improved maturation and fertilization potential [28]. The rise in estradiol (31.0 to 49.0 pg/mL) further supports enhanced follicular development, aligning with improved ovarian steroidogenesis post-weight loss [16].

4.5 Clinical Implications

1. AMH and AFC reductions post-surgery should be interpreted as physiological normalization, not infertility markers.
2. Clinicians should prioritize follicular quality over quantity when assessing reproductive potential post-bariatric surgery, using hormonal profiles as key indicators.

4.6 Limitations and Future Directions

- **Limitations:** Small sample size ($n = 32$), 12-month follow-up, and focus on sleeve gastrectomy limit generalizability.
- **Future Directions:** Larger cohorts, longer follow-ups (e.g., 18 months), and fertility outcome assessments (e.g., pregnancy rates) are needed. Comparative studies with other bariatric procedures could further elucidate effects.

5. Conclusion

Bariatric surgery markedly improves metabolic and reproductive health in morbidly obese women. Over 12 months, BMI, AMH, and AFC decreased, while SHBG, FSH, LH, and insulin sensitivity (HOMA-IR: 3.8 to 1.2) improved, alongside reduced free testosterone (all $p < 0.001$). These changes suggest enhanced follicular quality despite lower ovarian reserve markers, reflecting normalized ovarian function and potential fertility gains. By prioritizing quality over quantity, sleeve gastrectomy offers a dual benefit—metabolic correction and reproductive optimization—highlighting its value in obesity management. Long-term studies are needed to confirm these reproductive outcomes.

Declarations

Author Contribution

K.B. conceived and designed the study, performed the statistical analysis, interpreted the data, and wrote the main manuscript text. C.V. was responsible for patient sample collection and contributed to data analysis, along with G.D.E.M. contributed to patient recruitment and provided clinical guidance throughout the study. G.Z. and D.T. supervised the research project and provided critical revisions of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability

The datasets generated and analyzed during the current study are not publicly available due to patient privacy and institutional ethical restrictions but are available from the corresponding author on reasonable request.

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Figures

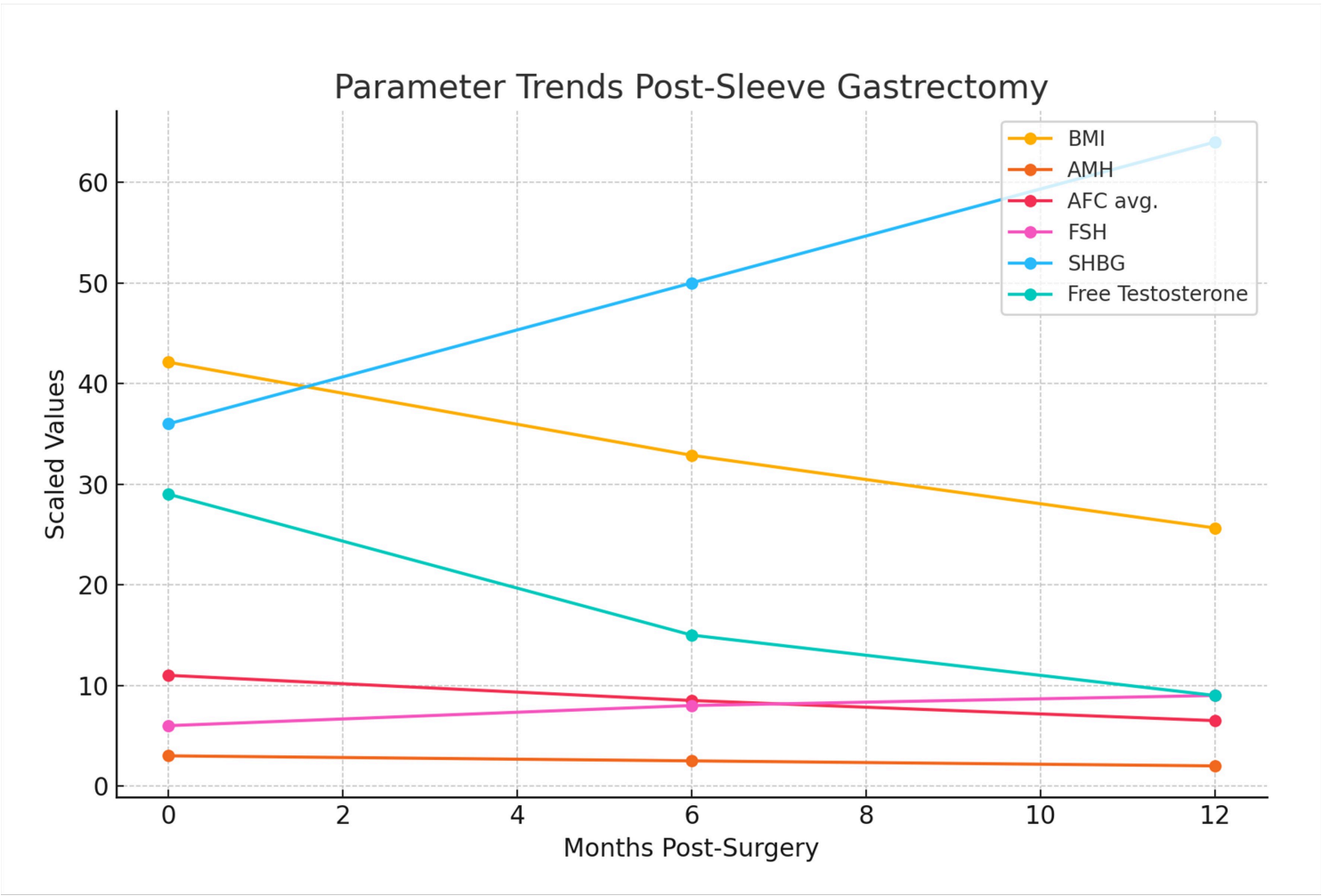


Figure 1

Trends in Key Parameters Over 12 Months

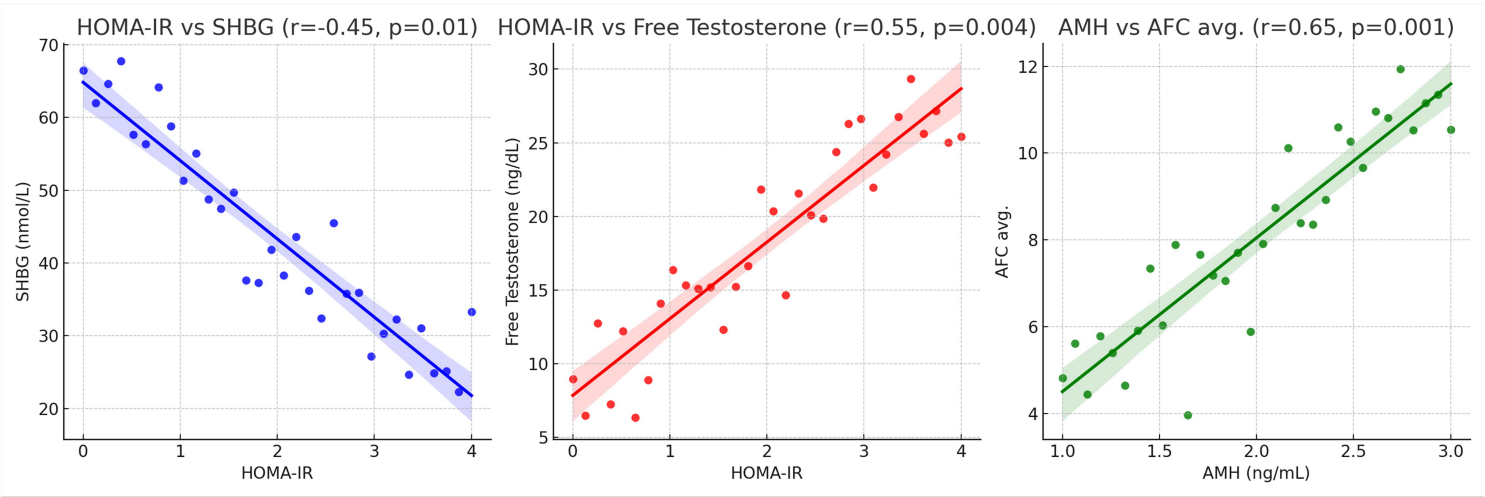


Figure 2

Correlations at 12 Months

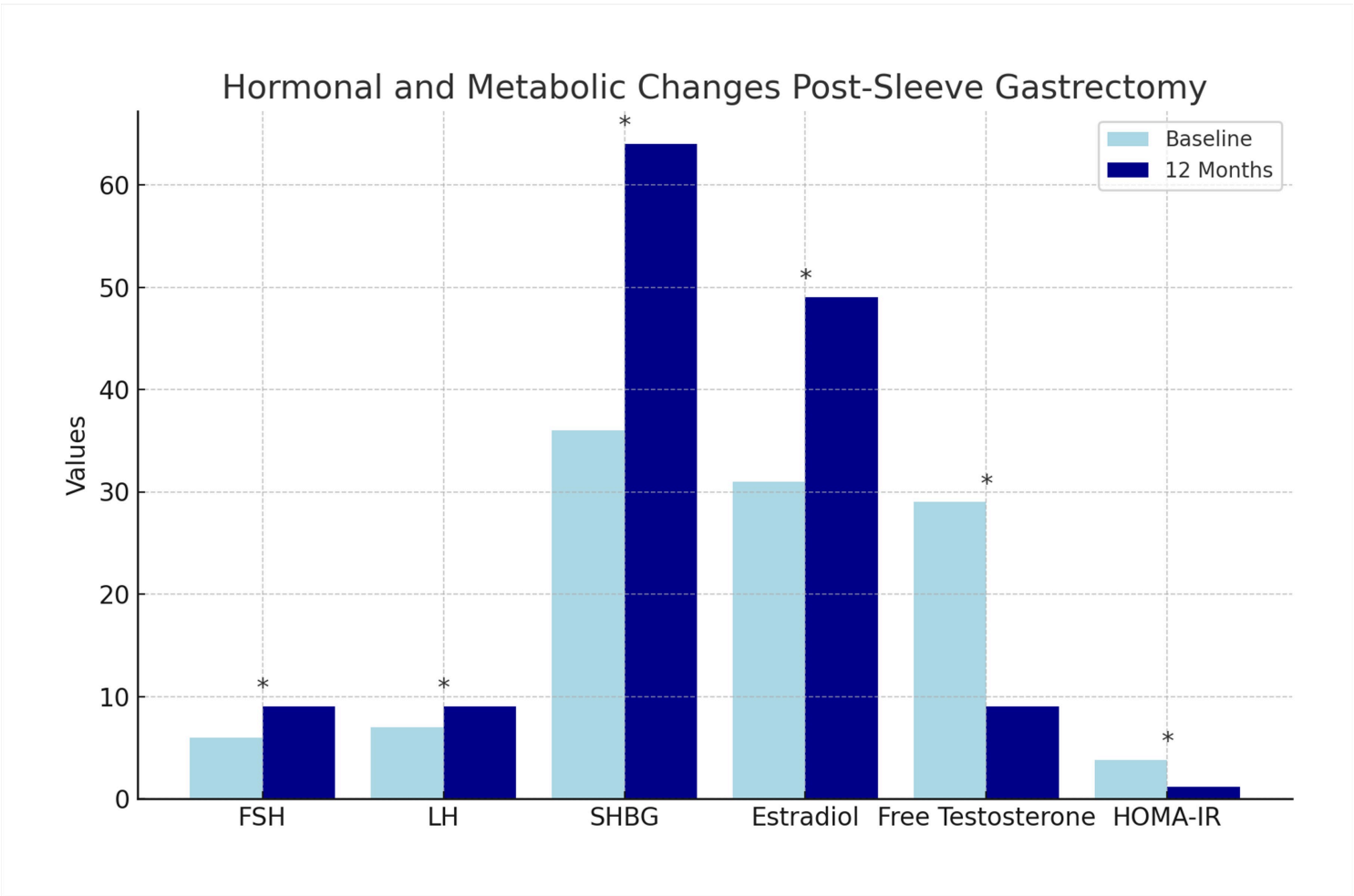


Figure 3

Hormonal and metabolic shifts at 12 months