Received: 24 August 2020 | Revised: 1 November 2020 | Accepted: 22 December 2010

DOI: 10.1002/ijgo.13570

CLINICAL ARTICLE

Obstetrics

Evaluating in vitro fertilization outcomes of patients with low body mass index following frozen-thawed embryo transfer

Margeaux Oliva[1] | Taraneh G. Nazem[1,2] | Joseph A. Lee[2] | Alan B. Copperman[1,2]

[1]Department of Obstetrics, Gynecology and Reproductive Science, Mount Sinai School of Medicine, New York, NY, USA

[2]Reproductive Medicine Associates of New York, New York, NY, USA

Correspondence
Margeaux Oliva, Icahn School of Medicine at Mount Sinai, 1176 Fifth Avenue, 9th Floor, New York, NY 10029, USA.
Email: margeaux.oliva@mountsinai.org

Abstract

Objective: To determine the relationship between patients with a low body mass index (BMI; calculated as weight in kilograms divided by the square of height in meters) and in vitro fertilization (IVF) outcomes following frozen-thawed embryo transfer (FET).

Methods: Retrospective cohort study including 12 618 women aged 20–46 years with an underweight (<18.5) or normal weight (18.5–24.9) BMI who underwent controlled ovarian stimulation for IVF in a private and academic IVF center between August 2002 and December 2019.

Results: Anti-Müllerian hormone, peak estradiol levels, number of MII oocytes, and fertilized oocytes were greater in the underweight group compared with the normal weight group. The total required gonadotropin dose was lower in the underweight patients compared with the normal weight patients. MII, fertilization, blastulation, and euploid rates did not differ before and after adjusting for confounders between BMI groups. In a cohort of 316 patients who underwent preimplantation genetic testing for aneuploidy and single euploid FET, pregnancy loss, pregnancy, clinical pregnancy, and live birth rates before and after controlling for covariates were similar between groups.

Conclusion: Although there are known fetal growth or obstetrical issues associated in patients with a low BMI, it is reassuring that these risks do not extend to embryologic or clinical outcomes from IVF treatment.

KEYWORDS
body mass index, fertilization rate, frozen-thawed embryo transfer, preimplantation genetic testing

1 | INTRODUCTION

Extremes of body mass index (BMI; calculated as weight in kilograms divided by the square of height in meters) have been shown to have deleterious effects on health outcomes.[1] A low BMI can result in many adverse health consequences, including impaired reproductive health and fecundity, as low energy reserves and body fat percentage cause metabolic and endocrine disturbances. Patients with low BMI have been found to experience alterations in steroid metabolism, insulin secretion, and changes in several hormones, including ghrelin, leptin, and adiponectin, which can contribute to female infertility.[2,3]

Given metabolic and hormonal disturbances observed in underweight patients, several studies have investigated the effect of low BMI on fertility. The current published literature has shown conflicting results.[4-12] Early data suggested a U-shaped relationship

between BMI and in vitro fertilization (IVF) outcomes with poorer oocyte and embryo quality, lower clinical pregnancy rates, and higher miscarriage rates in underweight women.[5-7] However, these studies were inconsistent in their definition of an underweight BMI and lacked statistical significance. More recent studies have shown no difference in obstetrical and IVF outcomes when comparing underweight and normal weight women.[4,8-12] However, some studies have found an increased number of oocytes retrieved among underweight patients,[4,9,11] possibly explained by a greater sensitivity to gonadotropin ovarian stimulation in underweight patients.

There is growing interest among reproductive medical providers to determine how patient BMI is associated with assisted reproductive technology treatment outcomes.[13] Although there have been some studies published on the relationship between patients with a low BMI and IVF outcomes, most are limited by small sample sizes and variations in the definition of underweight and normal BMI.[4,6,9,12,14,15] This study aimed to determine whether there is a difference in IVF outcomes following controlled ovarian stimulation (COS) for women with low or normal BMI. We also analyzed pregnancy outcomes in a cohort of patients who underwent single euploid frozen-thawed embryo transfer (FET).

2 | MATERIALS AND METHODS

This retrospective, single-center study included all patients with a documented BMI who underwent COS from August 2002 to December 2019. Trophectoderm biopsy and preimplantation genetic testing for aneuploidy (PGT-A) were performed on eligible blastocysts. IVF outcomes from all patients who underwent FET were evaluated. In the sub-analysis of single euploid FET, IVF outcomes from patients with aneuploid embryos or more than one embryo per transfer were excluded. Patients were categorized by BMI (underweight BMI < 18.5; normal weight BMI 18.5–24.9).[16] Patients with a BMI ≥ 25 were excluded. When analyzing single euploid FET pregnancy outcomes, patients who had an endometrial thickness <7 mm at embryo transfer were excluded, because many studies have demonstrated poorer obstetric outcomes below this cut-off.[17] This study was approved by an Icahn School of Medicine at Mount Sinai IRB with a waiver of consent for retrospective analysis of de-identified data.

Patients underwent COS for IVF as previously described.[18] When at least two mature follicles reached 18 mm, final oocyte maturation was induced with recombinant or purified human chorionic gonadotropin (hCG) (Ovidrel, EMB Serono) alone, leuprolide acetate alone (Lupron, AbbVie Inc.), or a "dual trigger" combination of leuprolide acetate and hCG. Patients underwent ultrasound-guided vaginal oocyte retrieval 36 h after surge.

Following vaginal oocyte retrieval, metaphase II (MII) oocytes were fertilized with intracytoplasmic sperm injection or conventional insemination. Embryos were cultured in Sage Quinn's Advantage Cleavage Medium (Cooper Surgical) until day 3. On day 3 after fertilization, embryos were cultured in glucose-rich G-2.5 Vitrolife Blastocyst Medium (Vitrolife) and supplement protein (10% SSS; Irvine Scientific) and underwent assisted hatching to facilitate trophectoderm herniation. Low-oxygen conditions were maintained during incubation.

In patients who used PGT-A, trophectoderm biopsy was performed on day 5 or day 6, contingent on embryo expansion and reaching a grade of 4BC or more (modified Gardner morphologic score). All blastocysts were vitrified and cryopreserved immediately after trophectoderm biopsy. Chromosome analysis was performed with quantitative real-time polymerase chain reaction or next-generation sequencing-based analysis.[19,20] Biopsied embryos received a genetic interpretation of euploid or aneuploid.

Cryopreservation and thawing techniques have been previously described.[18] After rewarming, embryo survival was determined according to the inner cell mass appearance and blastocoel re-expansion. Embryo transfer was performed after synthetic preparation of the endometrium. Patients were started on estradiol, and the endometrium was assessed weekly until a thickness of at least 7 mm was observed. Progesterone supplementation was then added, and the endometrial pattern was categorized as late proliferative, early secretory, or mid-late secretory, as described by Grunfeld et al.[21] Embryo thawing and transfer were performed after 5 days of progesterone supplementation.

Data were collected regarding patient baseline characteristics, including age, BMI, gravidity, parity, and markers of ovarian reserve (anti-Müllerian hormone, basal antral follicle count and day 3 follicle-stimulating hormone), ovarian stimulation protocol, ovulation trigger, total gonadotropin dose, and estradiol and progesterone levels at ovulatory surge. Following COS for IVF, the primary outcome of interest was fertilization rate (number of fertilized embryos/number of MII oocytes retrieved). Secondary outcomes included MII rate (number of MII oocytes/number of oocytes retrieved), blastulation rate (number of blastocysts/number of fertilized oocytes), and euploid rate (number of euploid embryos/number of embryos biopsied).

Single euploid FET cycle outcomes, including pregnancy loss rate (number of spontaneous abortions before 13 weeks/total FET cycles), pregnancy rate (number of positive serum hCG tests/total FET cycles), clinical pregnancy rate (number of intrauterine pregnancies with positive fetal heartbeat/total FET cycles), and live birth rate (number of deliveries of viable infants/total FET cycles) were calculated.

The data set was stratified based on BMI status, according to WHO classification.[15] Student's t test and χ^2/Fisher's exact tests were used to determine whether there were significant differences between BMI groups. A P value less than 0.05 was considered statistically significant. To assess differences in clinical outcomes, a multivariate logistic regression was performed for each outcome (fertilization rate, MII rate, blastulation rate, euploid rate, pregnancy loss rate, pregnancy rate, clinical pregnancy rate, live birth rate). Models were adjusted for covariates including age, markers of ovarian reserve, total gonadotropin dose, stimulation type, trigger type, estradiol and progesterone at the time of surge, number of embryos transferred, day of embryo transfer, endometrial type, and morphologic grade. Likelihood of clinical outcomes was presented as odds ratios (OR) with 95% confidence interval (CI). A post-hoc power calculation was performed for the primary outcome using a two-sided α level of 0.05 and 80% power.

Our study was powered to detect a 3.4% difference between groups given the sample size. A difference less than 3.4% was not considered to be clinically significant. Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA) and R statistical software version 3.4.3 (R Core Team, Vienna, Austria).

3 | RESULTS

The study identified 717 underweight women and 11 901 normal weight women who underwent COS for IVF (Table 1). Underweight patients were significantly younger (mean ± SD; 35.1 ± 5.2 years) than normal weight patients (37.1 ± 4.5 years, $P < 0.001$). There were no significant differences in gravidity and parity between groups. Patients in the underweight group had higher anti-Müllerian hormone levels (3.2 ± 4.0 ng/nl versus 2.6 ± 3.2 ng/nl, $P < 0.001$) and basal antral follicle count (12.1 ± 7.3 versus 11.0 ± 6.5, $P < 0.001$). However, day 3 follicle-stimulating hormone did not differ significantly between underweight and normal weight patients (6.4 mIU/ml versus 6.7 mIU/ml, $P = 0.087$). When comparing IVF stimulation protocols, underweight patients were more likely to undergo an antagonist protocol (463 [64.6%] versus 7253 [60.9%], $P = 0.002$) and have a leuprolide acetate trigger

TABLE 1 Baseline demographics, COS characteristics, and IVF laboratory outcomes[a]

	Underweight BMI (n = 717)	Normal BMI (n = 11 901)	*P* value
Age, years	35.1 ± 5.2	37.1 ± 4.5	<0.001
Nulligravid	335 (50.0%)	5143 (46.1%)	0.269
Nulliparous	464 (69.0%)	7922 (71.1%)	0.251
AMH, ng/ml	3.2 ± 4.0	2.6 ± 3.2	<0.001
BAFC	12.1 ± 7.3	11.0 ± 6.5	<0.001
Stimulation type			
Antagonist/estrogen priming	49 (6.8%)	992 (8.3%)	0.002
Antagonist	463 (64.6%)	7253 (60.9%)	
Clomiphene citrate/antagonist	12 (1.7%)	282 (2.4%)	
Downregulation	23 (3.2%)	635 (5.3%)	
MicroFlare	93 (13.0%)	1623 (13.6%)	
OCP/leuprolide acetate	53 (7.4%)	509 (4.3%)	
Flare	10 (1.4%)	340 (2.9%)	
Other	14 (2.0%)	267 (2.2%)	
Trigger type			
Dual	199 (28.1%)	3659 (31.2%)	0.006
hCG	461 (65.1%)	7571 (64.6%)	
Leuprolide acetate	48 (6.8%)	493 (4.2%)	
Day 3 FSH, mIU/ml	6.4 ± 4.0	6.7 ± 3.7	0.087
Surge E_2, pg/ml	2388 ± 1244	2125 ± 1141	<0.001
Surge P_4, ng/ml	1.0 ± 1.0	0.9 ± 0.6	<0.001
Total GND, IU	3582 ± 1540	3828 ± 1399	<0.001
Number of MIIs	11.3 ± 8.1	10.4 ± 7.4	<0.001
MII rate	0.78 ± 0.20	0.78 ± 0.19	0.444
Number of fertilized oocytes	8.4 ± 6.6	7.7 ± 6.1	0.003
Fertilization rate	0.73 ± 0.23	0.73 ± 0.23	0.956
Number of blastocysts	5.3 ± 5.5	4.8 ± 5.0	0.008
Blastulation rate	0.57 ± 0.34	0.57 ± 0.34	0.773
Number of euploid embryos	2.5 ± 2.6	2.2 ± 2.6	0.038
Euploid rate	0.47 ± 0.33	0.46 ± 0.35	0.562
Number of aneuploid embryos	2.1 ± 1.9	2.0 ± 1.8	0.107
Aneuploid rate	0.47 ± 0.33	0.50 ± 0.35	0.277

Abbreviations: AMH, anti-Müllerian hormone; BAFC, basal antral follicle count; BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters);COS, controlled ovarian stimulation; E_2, estradiol; FET, frozen-thawed embryo transfer; FSH, follicle-stimulating hormone; GND, gonadotropin; hCG, human chorionic gonadotropin; IVF, in vitro fertilization; OCP, oral contraceptive pill; P_4, progesterone.

[a]Values are given as mean ± SD or as number (percentage).

(48 [6.8%] versus 493 [4.2%], $P = 0.006$). Underweight patients had higher peak estradiol (2388 ± 1244 pg/ml versus 2125 ± 1141 pg/ml, $P < 0.001$) and progesterone (1.0 ± 1.0 ng/ml versus 0.9 ± 0.6 ng/ml, $P < 0.001$) levels than normal weight patients, but required a lower total gonadotropin dose (3582 ± 1540 IU versus 3828 ± 1399 IU, $P < 0.001$).

The sub-analysis included 15 underweight women and 201 normal weight women who underwent single euploid FET. Underweight and normal weight patients in this cohort had similar ages (35.1 ± 4.1 years versus 36.2 ± 4.2 years, $P = 0.336$), anti-Müllerian hormone levels (4.13 ± 2.15 ng/ml versus 3.30 ± 3.00 ng/ml, $P = 0.638$), basal antral follicle count (14.8 ± 4.1 versus 12.7 ± 6.8, $P = 0.306$), stimulation type ($P = 0.921$), trigger type ($P = 0.098$), day 3 follicle-stimulating hormone levels (5.55 ± 2.52 mIU/ml versus 6.26 ± 3.12 mIU/ml, $P = 0.459$), and estradiol (2907 ± 1090 pg/ml versus 2457 ± 1158 pg/ml, $P = 0.147$) and progesterone (0.9 ± 0.3 ng/ml versus 1.0 ± 0.4 ng/ml, $P = 0.766$) levels at time of surge (Table 2). Underweight patients required a significantly lower gonadotropin dose (2667 ± 1437 IU versus 3427 ± 1421 IU, $P = 0.048$).

The IVF cycle outcomes for 717 underweight and 11 901 normal weight patients are reported in Table 1. Underweight patients had a greater number of MII oocytes retrieved (11.3 ± 8.1 versus 10.4 ± 7.4, $P < 0.001$) and oocytes fertilized (8.4 ± 6.6 versus 7.7 ± 6.1, $P = 0.003$). The underweight and normal BMI groups had similar rates of MII oocytes (0.78 versus 0.78, $P = 0.444$, OR 0.86, 95% CI 0.58–1.30) and fertilization (0.73 versus 0.73, $P = 0.956$, OR 1.00, 95% CI 0.72–1.41), before and after adjusting for confounders. Underweight cohorts had a greater number of blastocysts than normal weight cohorts (5.3 ± 5.5 versus 4.8 ± 5.0, $P = 0.003$), but a similar blastulation rate (0.57 versus 0.57, $P = 0.773$, OR 1.03, 95% CI 0.83–1.30). Underweight patients had more euploid blastocysts (2.5 ± 2.6 versus 2.2 ± 2.6, $P = 0.038$), but no significant differences in aneuploidy were noted between groups. Underweight patients had similar euploid rates compared with normal weight patients in bivariate and multivariate analyses (0.47 versus 0.46, $P = 0.562$, OR 1.10, 95% CI 0.80–1.52).

Among the 216 patients who had single euploid FET, no differences in number of MII oocytes retrieved (15.6 ± 8.4 versus 13.2 ± 7.8, $P = 0.252$), fertilized oocytes (12.8 ± 6.5 versus 10.7 ± 6.8, $P = 0.240$), blastocysts (9.3 ± 4.9 versus 7.8 ± 5.3, $P = 0.312$), or euploid embryos (3.7 ± 1.8 versus 3.6 ± 2.9, $P = 0.819$) were demonstrated between underweight ($n = 15$) and normal weight patients ($n = 201$) (Table 2). Although the number of aneuploid embryos was greater in underweight patients (4.2 ± 3.0 versus 2.4 ± 2.1, $P = 0.003$), the aneuploid rate was comparable between the two groups (0.48 versus 0.38, $P = 0.151$). In line with the primary analysis, underweight and normal weight patients had similar rates of MII oocytes (0.75 versus 0.79, $P = 0.346$), fertilization (0.85 versus 0.81, $P = 0.395$), blastulation (0.73 versus 0.77, $P = 0.645$), euploid embryos (0.51 versus 0.60, $P = 0.171$) and aneuploid embryos (0.48 versus 0.38, $P = 0.151$).

Outcomes of FET were similar for underweight (n = 314) and normal weight (n = 4420) patients before and after controlling for confounders (Table 3). There were no significant differences in rates of pregnancy loss (7 [3.8%] versus 100 [3.5%], $P = 0.953$, OR 1.11, 95% CI 0.51–2.43), pregnancy (183 [58.3%] versus 2897 [56.2%], $P = 0.502$, OR 1.09, 95% 0.87–1.37) clinical pregnancy (148 [48.5%]

TABLE 2 Baseline demographics, COS characteristics, and IVF laboratory outcomes of single euploid FET[a]

	Underweight BMI (n = 15)	Normal BMI (n = 201)	*P* value
Age, years	35.1 ± 4.1	36.2 ± 4.2	0.336
Nulligravid	3 (23.1%)	54 (28.3%)	0.943
Nulliparous	5 (38.5%)	104 (54.2%)	0.454
AMH, ng/ml	4.13 ± 2.15	3.30 ± 3.00	0.638
BAFC	14.8 ± 4.1	12.7 ± 6.8	0.306
Stimulation type			
Antagonist/estrogen priming	0 (0.0%)	14 (7.0%)	0.921
Antagonist	14 (93.3%)	153 (76.1%)	
Clomiphene citrate/ antagonist	0 (0.0%)	1 (0.5%)	
Downregulation	0 (0.0%)	5 (2.5%)	
MicroFlare	0 (0.0%)	10 (5.0%)	
OCP/leuprolide acetate	1 (6.7%)	12 (6.0%)	
Flare	0 (0.0%)	0 (0.0%)	
Other	0 (0.0%)	6 (3.0%)	
Trigger type			
Dual	4 (26.7%)	62 (32.1%)	0.098
hCG	8 (53.3%)	121 (62.7%)	
Leuprolide acetate	3 (20.0%)	10 (5.2%)	
Day 3 FSH, mIU/ml	5.55 ± 2.52	6.26 ± 3.12	0.459
Surge E_2, pg/ml	2907 ± 1090	2457 ± 1158	0.147
Surge P_4, ng/ml	0.9 ± 0.3	1.0 ± 0.4	0.766
Total GND, IU	2667 ± 1437	3427 ± 1421	0.048
Number of MIIs	15.6 ± 8.4	13.2 ± 7.8	0.252
MII rate	0.75 ± 0.18	0.79 ± 0.16	0.346
Number of fertilized oocytes	12.8 ± 6.5	10.7 ± 6.8	0.240
Fertilization rate	0.85 ± 0.16	0.81 ± 0.15	0.395
Number of blastocysts	9.3 ± 4.9	7.8 ± 5.3	0.312
Blastulation rate	0.73 ± 0.17	0.77 ± 0.32	0.645
Number of euploid embryos	3.7 ± 1.8	3.6 ± 2.9	0.819
Euploid rate	0.51 ± 0.21	0.60 ± 0.26	0.171
Number of aneuploid embryos	4.2 ± 3.0	2.4 ± 2.1	0.003
Aneuploid rate	0.48 ± 0.20	0.38 ± 0.25	0.151

Abbreviations: AMH, anti-Müllerian hormone; BAFC, basal antral follicle count; BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters);COS, controlled ovarian stimulation; E_2, estradiol; FET, frozen-thawed embryo transfer; FSH, follicle-stimulating hormone; GND, gonadotropin; hCG, human chorionic gonadotropin; IVF, in vitro fertilization; OCP, oral contraceptive pill; P_4, progesterone.

[a]Values are given as mean ± SD or as number (percentage).

versus 2408 [47.3%], *P* = 0.716, OR 1.05, 95% CI 0.83–1.33) or live birth (122 [45.2%] versus 1972 [44.6%], *P* = 0.904, OR 1.02, 95% CI 0.80–1.31).

Underweight (n = 15) and normal weight (n = 184) patients who underwent single euploid FET also had similar rates of pregnancy loss (2 [18.2%] versus 5 [4.3%], *P* = 0.113, OR 4.93, 95% CI 0.84–29.11), pregnancy (12 [80.0%] versus 118 [64.1%], *P* = 0.269, OR 2.24, 95% 0.61–8.21), clinical pregnancy (7 [46.7%] versus 99 [53.8%], *P* = 0.604, OR 0.75, 95% CI 0.26–2.16) and live birth (5 [45.5%] versus 89 [54.6%], *P* = 0.756, OR 0.69, 95% CI 0.20–2.36) (Table 4).

4 | DISCUSSION

The present study is one of the largest to evaluate the relationship between low BMI and IVF treatment outcomes in patients who underwent COS. Although some differences in baseline demographics and COS characteristics existed between BMI groups, we failed to show that an underweight BMI caused disparities in clinical outcomes, particularly with patients who underwent single euploid FET. Extreme alterations in body composition and decreased energy availability associated with low BMI have been shown to result in many negative health consequences, but these changes do not appear to be associated with impaired embryo quality or quantity or adverse pregnancy outcomes.

Many researchers have found that women with low BMI have similar IVF and pregnancy outcomes to those with normal BMI.[8-12] These studies are in contrast to the early theory of a U-shaped association between an underweight BMI and pregnancy outcomes after IVF treatment and further suggest that beyond embryo quality and quantity, pregnancy outcomes following IVF are not impacted by extreme alterations in BMI.[4-8,15] The present study's findings bolster these results by focusing on pregnancy outcomes in patients who underwent PGT-A and single euploid FET. With more advanced IVF protocols and the introduction of PGT-A, there has been a shift in clinical practice from the transfer of multiple embryos to a single euploid embryo. All of these changes have translated into better clinical outcomes, with reductions in multiple births and obstetric complications. In our sub-analysis, we confirm that patients who undergo single euploid FET have similar pregnancy outcomes, regardless of BMI group.

Our study has some limitations. First, the retrospective design may present a selection bias in our population of patients. Furthermore, given the retrospective nature of the study, we were not able to account for all patient characteristics that are known to affect IVF outcomes, including smoking and duration of infertility, or control for differences in cycle characteristics between the two groups, such as stimulation protocol. However, we were able to adjust our analysis for many other impactful patient characteristics, including age, gravidity, parity, and markers of ovarian reserve. There was also a significantly lower number of patients who were underweight compared with normal weight, which may skew the results.

Our study has several strengths. Our results shed new light on the relationship between an underweight BMI and embryo quality and quantity, as the lack of a negative relationship is extremely valuable and encouraging for both patients undergoing IVF and those pursuing elective embryo and oocyte cryopreservation. This is also one of the largest studies to analyze the relationship between a low BMI and IVF outcomes and the validity of our results are strengthened by the sample size. Our sub-analysis focusing on single euploid FET also expanded upon previous studies by demonstrating a neutral relationship between BMI and pregnancy outcomes when using modern IVF practices, particularly PGT-A.

This study sought to investigate the relationship between an underweight BMI and IVF outcomes and detected a clinically negligible impact of a low BMI. We found that although there was an increased number of MII oocytes retrieved and fertilized in the underweight group, MII and fertilization rates did not differ significantly from patients of normal weight. Underweight patients were more likely to have embryos that achieved blastulation and were euploid, but had similar rates of blastulation and ploidy as normal weight patients. For patients that underwent single euploid FET, we observed no differences in pregnancy loss, pregnancy, clinical pregnancy, and live birth rates among underweight and normal weight cohorts. Although this study provides reassurance to underweight patients undergoing IVF, providers are still encouraged to focus on discussing nutritional and exercise guidelines that may further optimize preconception health.

TABLE 3 Frozen embryo transfer pregnancy outcomes

	Underweight BMI (n = 314)	Normal BMI (n = 4420)	*P* value
Pregnancy loss rate (%)	7 (3.8)	100 (3.5)	0.953
Pregnancy rate (%)	183 (58.3)	2897 (56.2)	0.502
Clinical pregnancy rate (%)	148 (48.5)	2408 (47.3)	0.716
Live birth rate (%)	122 (45.2)	1972 (44.6)	0.904

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

TABLE 4 FET pregnancy outcomes of single euploid FET

	Underweight BMI (n = 15)	Normal BMI (n = 184)	*P* value
Pregnancy loss rate (%)	2 (18.2)	5 (4.3)	0.113
Pregnancy rate (%)	12 (80.0)	118 (64.1)	0.269
Clinical pregnancy rate (%)	7 (46.7)	99 (53.8)	0.604
Live birth rate (%)	5 (45.5)	89 (54.6)	0.756

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); FET, frozen embryo transfer.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

AUTHOR CONTRIBUTIONS

MO, TGN, JAL, and ABC all contributed to the study design, manuscript writing, and approval of the final manuscript version. MO and TGN analyzed the data.

REFERENCES

1. Global BMI Mortality Collaboration, Di Angelantonio E, Bhupathiraju SN, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet*. 2016;388:776-786.
2. Misra M, Klibanski A. Endocrine consequences of anorexia nervosa. *Lancet Diabetes Endocrinol*. 2014;2:581-592.
3. Warren MP. Endocrine manifestations of eating disorders. *J Clin Endocrinol Metab*. 2011;96:333-343.
4. Fedorcsák P, Dale PO, Storeng R, et al. Impact of overweight and underweight on assisted reproduction treatment. *Hum Reprod*. 2004;19:2523-2528.
5. Wang JX, Davies M, Norman RJ. Body mass and probability of pregnancy during assisted reproduction treatment: retrospective study. *BMJ*. 2000;321:1320-1321.
6. Li Y, Yang D, Zhang Q. Impact of overweight and underweight on IVF treatment in Chinese women. *Gynecol Endocrinol*. 2010;26:416-422.
7. Winter E, Wang J, Davies MJ, Norman R. Early pregnancy loss following assisted reproductive technology treatment. *Hum Reprod*. 2002;17:3220-3223.
8. Insogna IG, Lee MS, Reimers RM, Toth TL. Neutral effect of body mass index on implantation rate after frozen-thawed blastocyst transfer. *Fertil Steril*. 2017;108(5):770-776.e1.
9. Singh N, Gupta P, Mittal S, Malhotra N. Correlation of body mass index with outcome of in vitro fertilization in a developing country. *Arch Gynecol Obstet*. 2012;285:259-263.
10. Provost MP, Acharya KS, Acharya CR, et al. Pregnancy outcomes decline with increasing body mass index: analysis of 239,127 fresh autologous in vitro fertilization cycles from the 2008–2010 Society for Assisted Reproductive Technology registry. *Fertil Steril*. 2016;105:663-669.
11. Kawwass JF, Kulkarni AD, Hipp HS, Crawford S, Kissin DM, Jamieson DJ. Extremities of body mass index and their association with pregnancy outcomes in women undergoing in vitro fertilization in the United States. *Fertil Steril*. 2016;106:1742-1750.
12. Bellver J, Ayllón Y, Ferrando M, et al. Female obesity impairs in vitro fertilization outcome without affecting embryo quality. *Fertil Steril*. 2010;93:447-454.
13. Holter H, Anderheim L, Bergh C, Moller A. First IVF treatment–short-term impact on psychological well-being and the marital relationship. *Hum Reprod*. 2006;21:3295-3302.
14. Goldman KN, Hodes-Wertz B, McCulloh DH, Flom JD, Grifo JA. Association of body mass index with embryonic aneuploidy. *Fertil Steril*. 2015;103:744-748.
15. Pinborg A, Gaarslev C, Hougaard CO, et al. Influence of female bodyweight on IVF outcome: a longitudinal multicentre cohort study of 487 infertile couples. *Reprod Biomed Online*. 2011;23:490-499.
16. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser*. 2000;894:1-253.
17. Kasius A, Smit J, Torrance H, et al. Endometrial thickness and pregnancy rates after IVF: a systemic review and meta-analysis. *Hum Reprod Update*. 2014;20:530-541.
18. Rodriguez-Purata J, Lee J, Whitehouse M, et al. Reproductive outcome is optimized by genomic embryo screening, vitrification, and subsequent transfer into a prepared synchronous endometrium. *J Assist Reprod Genet*. 2016;33:401-412.
19. Treff NR, Tao X, Ferry KM, Su J, Taylor D, Scott RT Jr. Development and validation of an accurate quantitative real-time polymerase chain reaction-based assay for human blastocyst comprehensive chromosomal aneuploidy screening. *Fertil Steril*. 2012;97:819-824.
20. Fiorentino F, Biricik A, Bono S, et al. Development and validation of a next-generation sequencing-based protocol for 24-chromosome aneuploidy screening of embryos. *Fertil Steril*. 2014;101:1375-1382.
21. Grunfeld L, Walker B, Bergh PA, Sandler B, Hofmann G, Navot D. High-resolution endovaginal ultrasonography of the endometrium: a noninvasive test for endometrial adequacy. *Obstet Gynecol*. 1991;78:200-204.

How to cite this article: Oliva M, Nazem TG, Lee JA, Copperman AB. Evaluating in vitro fertilization outcomes of patients with low body mass index following frozen-thawed embryo transfer. *Int J Gynecol Obstet*. 2021;00:1–6. https://doi.org/10.1002/ijgo.13570