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Extremities of body mass index and their association with pregnancy outcomes in women undergoing in vitro fertilization in the United States

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Abstract

Objective: To investigate the associations among underweight body mass index (BMI), pregnancy, and obstetric outcomes among women using assisted reproductive technology (ART).

Design: Retrospective cohort study using national data and log binomial regression.

Setting: Not applicable.

Patient(s): Women undergoing IVF in the United States from 2008 to 2013.

Intervention(s): None.

Main Outcome Measure(s): Pregnancy outcomes (intrauterine pregnancy, live birth rates) per transfer, miscarriage rate per pregnancy, and low birth weight and preterm delivery rates among singleton and twin pregnancies.

Result(s): For all fresh autologous in vitro fertilization (IVF) cycles in the United States from 2008 to 2013 (n = 494,097 cycles, n = 402,742 transfers, n = 180,855 pregnancies) reported to the national ART Surveillance System, compared with normal weight women, underweight women had a statistically significant decreased chance of intrauterine pregnancy (adjusted risk ratio [aRR] 0.97; 95% confidence interval [CI], 0.96–0.99) and live birth (aRR 0.95; 95% CI, 0.93–0.98) per transfer. Obese women also had a statistically decreased likelihood of both (aRR 0.94; 95% CI, 0.94–0.95; aRR 0.87; 95% CI, 0.86–0.88, respectively). Among cycles resulting in singleton pregnancy, both underweight and obese statuses were associated with increased risk of low birth weight (aRR 1.39; 95% CI, 1.25–1.54, aRR 1.26; 95% CI, 1.20–1.33, respectively) and preterm delivery (aRR 1.12; 95% CI, 1.01–1.23, aRR 1.42; 95% CI, 1.36–1.48, respectively). The association between underweight status and miscarriage was not statistically significant (aRR

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1.04; 95% CI, 0.98–1.11). In contrast, obesity was associated with a statistically significantly increased miscarriage risk (aRR 1.23; 95% CI, 1.20–1.26).

Conclusion(s): Among women undergoing IVF, prepregnancy BMI affects pregnancy and obstetric outcomes. Underweight status may have a limited impact on pregnancy and live-birth rates, but it is associated with increased preterm and low-birth-weight delivery risk. Obesity negatively impacts all ART and obstetric outcomes investigated.

Keywords

IVF; miscarriage; outcomes; preterm; underweight

As the obesity epidemic continues to plague the United States, numerous reports have been published and recommendations made regarding the negative impact of obesity on fertility (1), assisted reproductive technology (ART) effectiveness (2–9), and pregnancy and obstetric outcomes (5, 10). By contrast, limited and conflicting data exist on the impact of being underweight (body mass index [BMI] <18.5 kg/m^2), admittedly a less common problem, on fertility and the effectiveness of ART. A few small studies to date have evaluated the impact of low BMI on ART outcomes and have not found a statistically significant difference in underweight women as compared with their normal-weight counterparts (11–14). Nonetheless, many clinicians recommend weight gain in women with low BMI who desire in vitro fertilization (IVF) treatment based on small retrospective studies that have reported a lower absolute clinical pregnancy rate among underweight women using ART (11, 15).

Many clinicians are aware of the association between obesity and miscarriage; however, existing studies suggest that both extremities of BMI, both underweight and obese statuses, may be associated with increased miscarriage risk in the general population (16) and in the ART population (17). Additionally, prepregnancy underweight status coupled with poor weight gain has been associated with worse obstetric outcomes such as preterm delivery, preterm premature rupture of membranes, and low birth weight in the general population (18–21).

To our knowledge, the impact of prepregnancy underweight status on IVF and perinatal outcomes has not been investigated among a large cohort of ART-conceived pregnancies. We used National ART Surveillance System (NASS) data from 2008 through 2013 to investigate the association between BMI and ART on pregnancy and obstetric outcomes. The overweight BMI categories were included to put the underweight results in perspective. We hypothesized that underweight status, like overweight status, would be associated with an increased risk of adverse ART and obstetric outcomes. We also calculated trends in BMI among women undergoing ART during the 5-year interval.

MATERIALS AND METHODS

The Centers for Disease Control and Prevention’s National ART Surveillance System (NASS), a federally mandated, validated system that includes over 98% of all ART cycles performed in the United States, was used to characterize the relationship between BMI

and obstetric outcomes of ART (22). The National ART Surveillance System (NASS) includes information from all 50 states and Puerto Rico on patient demographics, medical and obstetric history, and infertility diagnoses, detailed parameters of each treatment cycle, and, if applicable, the resultant pregnancy outcome (Fertility Clinic Success Rate and Certification Act of 1992 [FCSRCA], Public Law No. 102–493, October 24, 1992) (22). Notably, height and weight were added as collected variables in NASS in 2007.

This study included all fresh autologous (nondonor) ART cycles reported to NASS between 2008 and 2013 with BMI data available. Donor and frozen cycles were excluded to limit the heterogeneity of the study group and to minimize confounding. Among all fresh autologous ART cycles from 2008–2013 (n = 602,640 cycles), height and weight were reported for 82.0% (n = 494,097 cycles). Height, weight, or both height and weight were missing for 108,543 cycles; 16.4% of all cycles (n = 98,640) had missing height data, and 16.9% (n = 102,030) had missing weight data. The patents' BMI was calculated as reported weight in kilograms per meter squared (reported height) at time of cycle start.

We began by describing trends in BMI over the 6-year study period. The number and percentage of all ART cycles for which the woman was underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2), or obese (BMI ≥ 30 kg/m^2) were calculated for each year. Simple linear regression where the outcome was the percentage and the explanatory variable was the calendar year was used to check for trend.

Among all fresh autologous IVF cycles for which BMI could be calculated during the study period (n = 494,097), we described patient and cycle characteristics in each of the BMI categories. Next, we calculated cancellation rates per cycle and pregnancy outcomes, namely, intrauterine pregnancy rate and live-birth rate (≥ 20 weeks) per noncancelled cycle for which a transfer was performed (n = 402,742 cycles). Among cycles resulting in intrauterine pregnancy (n = 180,855 cycles), we calculated the miscarriage rate. Among singleton (n = 126,552) and twin (n = 49,499) gestations, we calculated preterm (<37 weeks) and low-birth-weight (<2,500 g) delivery rates. A twin pregnancy in which one twin was <2,500 g was considered a preterm delivery.

Using log-binomial regression to estimate the relative risk, we investigated the relationship between BMI and pregnancy outcomes, first for underweight versus normal weight, and then for obese versus normal weight. A similar process was repeated to explore the relationship between degree of thinness (severe thinness BMI <16.0 kg/m^2, moderate thinness BMI 16.0–16.9 kg/m^2, and mild thinness BMI 17.0–18.49 kg/m^2) and obstetric outcomes as compared with normal weight. Of the considered potential confounders (age, number of prior pregnancies, cycle history, stimulation type, number of oocytes retrieved, use of intracytoplasmic sperm injection, use of assisted hatching, number of embryos transferred, stage of embryo at transfer, number of supernumerary embryos cryopreserved, infertility diagnosis as specifically diminished ovarian reserve, male factor infertility, endometriosis, ovulatory dysfunction, tubal factor infertility, uterine factor infertility, and unexplained), backward elimination with α level of 0.05 was used to determine and retain only statistically significant confounders. Race/ethnicity was not considered in the primary models due to the

large amount of missing data (33.9%). However, a sensitivity analysis of only those cycles for which race/ethnicity was reported was performed. Finally, we calculated pregnancy and live-birth rates per noncancelled cycle resulting in transfer and the miscarriage rate per cycle that resulted in pregnancy among all fresh autologous IVF cycles from 2008–2013 by single unit of BMI (range <15.0 to ≥ 40 kg/m^2).

All analyses were conducted using SAS version 9.3 (SAS Institute Inc). This study was approved by an institutional review board of the Centers for Disease Control and Prevention.

RESULTS

Over the study period, the percentage of cycles involving underweight women statistically significantly decreased from 2.9% to 2.6% while the percentage of cycles in which the woman was obese statistically significantly increased from 17.8% to 19.0%. The majority (55.0%) of women for all study years were of normal weight. Among 494,097 ART cycles started between 2008 and 2013 for which BMI was reported, 13,678 (2.8%) of the cycles involved underweight women with a low BMI, and 91,646 (18.5%) of cycles involved obese women (Table 1).

Among ART cycles performed between 2008 and 2013 for which we have BMI information, a larger percentage of underweight women as compared with women in other BMI categories were under 35 years old, of Asian or Pacific Islander origin, had an infertility diagnosis of endometriosis, diminished ovarian reserve, or tubal factor infertility, had a maximum serum follicle-stimulating hormone (FSH) value of ≥ 10.0 mIU/mL, and had no prior pregnancies (see Table 1). As compared with women in the other BMI categories, obese women more frequently were of non-Hispanic Black race, held a diagnosis of ovulatory dysfunction or tubal factor infertility, had a maximum FSH concentration of ≤ 5.0 mIU/mL, had a history of two or more prior pregnancies, and had a history of two or more spontaneous abortions. Most frequently among all BMI categories, gonadotropin-releasing hormone antagonist protocols were used, 10 or more oocytes were retrieved, two embryos were transferred, cleavage-stage (days 2 to 3) embryos were transferred, intracytoplasmic sperm injection was used, assisted hatching was not performed, and no embryos were cryopreserved.

Among all cycles, the cancellation rates were comparable in underweight and normal BMI groups, but obesity as compared with normal BMI was associated with a slight but statistically significant increased risk of cancellation (adjusted risk ratio [aRR] 1.05; 95% confidence interval [CI], 1.03–1.07) (Table 2). Among noncancelled transfers in comparison to women with normal BMI, underweight women had a statistically significantly decreased chance of intrauterine pregnancy (aRR 0.97; 95% CI, 0.96–0.99) and live birth (aRR 0.95; 95% CI, 0.93–0.98) per transfer, as did obese women (aRR 0.94; 95% CI, 0.94–0.95 and aRR 0.87; 95% CI, 0.86–0.88, respectively).

Among cycles resulting in pregnancy, the association between low BMI and miscarriage was not statistically significant (aRR 1.04; 95% CI, 0.98–1.11). In contrast, obesity as compared with normal weight was associated with a statistically significantly increased miscarriage

risk (aRR 1.23; 95% CI, 1.20–1.26). Among cycles resulting in singleton pregnancy, both underweight and obese statuses were associated with increased risk of low-birth-weight (aRR 1.39; 95% CI, 1.25–1.54 and aRR 1.26; 95% CI, 1.20–1.33, respectively) and preterm delivery (aRR 1.12; 95% CI, 1.01–1.23 and aRR 1.42; 95% CI, 1.36–1.48, respectively).

Among cycles resulting in twin pregnancy, underweight as compared with normal weight status was associated with increased risk of low birth weight (aRR 1.14; 95% CI, 1.10–1.17) but not preterm delivery (aRR 1.04; 95% CI, 0.99–1.09). Obese weight was associated with increased risk of preterm delivery (aRR 1.06; 95% CI, 1.03–1.08) and low birth weight (aRR 0.95; 95% CI, 0.94–0.97). Of all the twin live births (n = 40,832), 7,990 (19.6%) women delivered at <34 weeks' gestation. Among twin live births in underweight women, 224 (20.2%) delivered at <34 weeks. Among twin live births in normal weight and obese women, 4,343 (18.7%) and 1,466 (21.3%) delivered at <34 weeks, respectively.

Additionally, a sensitivity analyses incorporating race/ethnicity was performed. It noted no statistically significant difference in the adjusted relative risk in any of the comparisons (results not shown).

An analysis of severe, moderate, and mild thinness as compared with normal weight found no clinically significant differences between degree of thinness and cancellation rate or ART pregnancy outcomes (intrauterine pregnancy, live birth, and miscarriage) except for a decreased chance of live birth for moderate thinness compared with normal weight (aRR 0.92; 95% CI, 0.86–0.99), a decreased likelihood of intrauterine pregnancy for mild thinness compared with normal weight (aRR 0.98; 95% CI, 0.96–0.99), and a decreased chance of live birth for mild thinness compared with normal weight (aRR 0.96; 95% CI, 0.94–0.98) (Table 3). All degrees of thinness among both singleton and twin pregnancies were associated with an increased risk of low-birth-weight delivery as compared with normal weight women; however, only severe thinness among twin pregnancies was associated with increased risk of preterm delivery.

When the pregnancy, live-birth, and miscarriage rates were explored against the unit value of BMI, a range of optimal BMI was clearly visible (Fig. 1). The pregnancy rate was highest in women whose BMI was between 19.0 and 22.9 kg/m^2 (46.1% to 46.3%) and fell with increasing BMI to 38.8% in BMI ≥ 40 kg/m^2 (see Fig. 1A). Similarly, the live-birth rate was highest in women whose BMI was between 19.0 and 22.9 kg/m^2 (38.6% to 38.8%) and fell with increasing BMI to a nadir of 29.4% in BMI ≥ 40 kg/m^2. The miscarriage rate increased with increasing BMI from 12.3% among women with BMI 15.0–15.9 kg/m^2 to 22.0% among women with BMI ≥ 40 kg/m^2 (see Fig. 1B).

DISCUSSION

Over the study period, the majority of women for all study years were of normal weight; the percentage of cycles involving underweight women statistically significant decreased while the percentage of cycles in which the female was obese statistically significantly increased. The best outcomes were observed among women of normal weight; for those of abnormal

weight, obesity was associated with greater risk of adverse obstetric and obstetric outcomes than was underweight status.

According to the National Center for Health Statistics, among the general adult population during the study period the percentage of underweight women ranged from 1.6% to 1.7% while the percentage of obese women ranged from 33.7% to 34.9% (23, 24). The percentage of obese women (18.5%) within the ART population is smaller for obese women than in the general population. Part of this difference may be attributable to purposeful patient selection; women with BMIs outside the normal range may be discouraged from using reproductive services.

As compared with normal weight women, underweight women had a similar absolute percentage chance of intrauterine pregnancy, live birth, and miscarriage after IVF. After adjusting for possible confounders, the adjusted relative risks for these ART outcomes were statistically significant but likely of limited clinical significance, as they very closely approached 1. These findings, in a large cohort of women, support those of several smaller studies that suggested no statistically significant impact of low BMI on the ART outcomes of pregnancy and live birth (12–15). Our results do, however, contradict the reported association of low BMI with increased miscarriage risk in the ART population (17). The adjusted relative risk of delivering a low-birth-weight or preterm infant, singleton or twin, was elevated among underweight women, a finding consistent with prior studies that suggest that underweight women have an increased likelihood of poor obstetric outcomes, including preterm birth and low-birth-weight delivery (19–21). Our study is among the first to examine this relationship in the IVF population. Notably, we were unable to control for maternal weight gain during pregnancy, which also contributes to the risk of preterm birth and low-birth-weight possibly due to nutritional deficiencies. The fact that the impact of underweight maternal status on preterm delivery was less notable among twin pregnancies may reflect the underlying increased risk of preterm delivery associated with all twin pregnancies independent of maternal weight at time of conception.

In contrast to the findings for underweight women, the absolute percentage chance of ART success, pregnancy, and live birth was statistically significantly lower among the obese women as compared with the normal weight women. Obesity was also associated with a statistically significantly increased risk of miscarriage. These findings are consistent with multiple prior studies that suggest an association between obesity and impaired fertility (1), worse ART outcomes (2–9), and a statistically significantly increased miscarriage and obstetric risk (25, 26).

Our study is limited by its cycle-based rather than patient-based nature, by the lack of some patient medical information such as tobacco use, nonfertility-related medical history, obstetric complications, interpregnancy interval, pregnancy weight gain, and the lack of embryo quality data. To minimize the effects of lack data on embryo quality, we were able to control for the number of supernumerary embryos cryopreserved, which has been shown to correlate with embryo quality (27) and number of prior failed IVF cycles. Additionally, the study is limited by the quality of height and weight data entered by clinicians and by the fact that 18% of BMI data are missing. Potential bias exists in that the group that comprises

the missing data may be different from those for whom we have data; however, we have no reason to believe that the two groups are inherently different.

This study is among the first of its size to focus on the impact of low BMI on ART outcomes. It is strengthened not only by the large sample size but also by its generalizability in that it includes all reporting clinics in the United States. We were also able to control for patient and ART cycle characteristics that impact pregnancy and obstetric outcomes, and a sensitivity analysis that incorporated BMI noted no statistically significant differences in adjusted relative risks.

CONCLUSION

Among women undergoing IVF, prepregnancy BMI affects pregnancy and obstetric outcomes. Although underweight status may have limited impact on ART success (namely, pregnancy and live-birth rates), it is associated with increased risk of preterm and low-birth-weight delivery. Obese status negatively impacts all favorable outcomes except birthweight among singletons. Independent of pregnancy weight gain, prepregnancy BMI is a modifiable characteristic that has obstetric implications. Whenever feasible, particularly among the ART population that is afforded preconception counseling, physicians should encourage women to reach a normal BMI before attempting conception.

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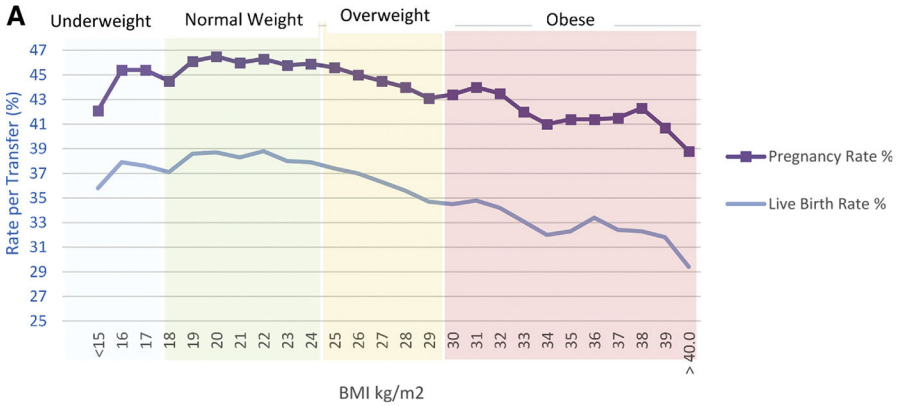

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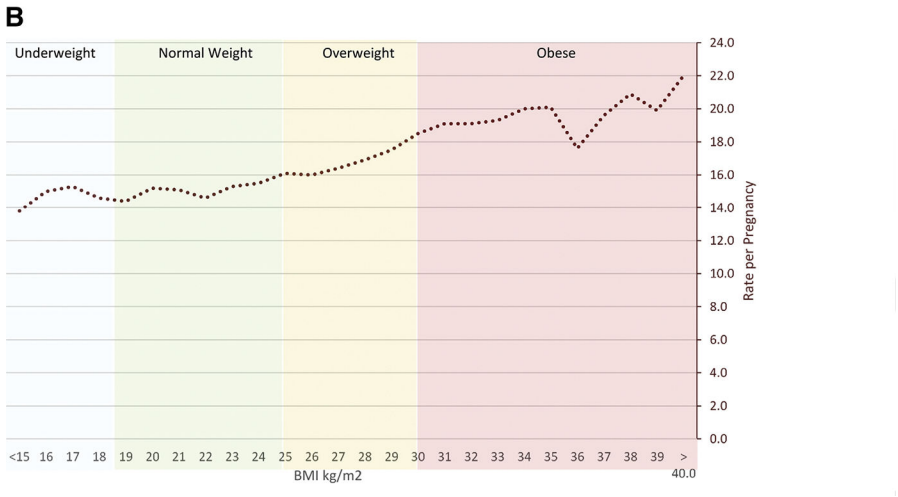

FIGURE 1.

(**A**) Pregnancy and live-birth rate per transfer by body mass index, fresh autologous IVF cycles, 2008–2013. (**B**) Miscarriage rate among all pregnancies by body mass index, fresh autologous IVF cycles, 2008–2013.

TABLE 1

Patient and cycle characteristics, fresh autologous IVF cycles, 2008–2013.

	Underweight < 18.5 (kg/m^2)		Normal weight 18.5–24.9 (kg/m^2)		Overweight 25.0–29.9 (kg/m^2)		Obese >30 (kg/m^2)		
Patient characteristics	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**Chi square**
Totals	13,678	2.8	271,985	55.0	116,788	23.6	91,646	18.5	
Age (y)									
<35	6,656	48.7	116,697	42.9	47,278	40.5	37,421	40.8	< .0001
35–37	2,880	21.1	57,970	21.3	24,829	21.3	19,763	21.6	
38–40	2,397	17.5	54,459	20.0	24,907	21.3	19,728	21.5	
≥41	1,745	12.8	42,859	15.8	19,774	16.9	14,734	16.1	
Race/ethnicity									
Only non-Hispanic white	5,494	40.2	129,235	47.5	53,618	45.9	43,235	47.2	< .0001
Only non-Hispanic black	229	1.7	6,975	2.6	8,238	7.1	8,668	9.5	
Only Aslan Pacific Islander	2,459	18.0	28,729	10.6	8,337	7.1	3,465	3.8	
Only Hispanic	521	3.8	13,287	4.9	7,420	6.4	6,087	6.6	
Other	15	0.1	380	0.1	220	0.2	197	0.2	
Missing	4,960	36.3	93,379	34.3	38,955	33.4	29,994	32.7	
Infertility diagnosis									
Diminished ovarian reserve	3,666	26.8	72,114	26.5	28,918	24.8	19,752	21.6	< .0001
Male factor	4,865	35.6	97,851	36.0	44,160	37.8	35,221	38.4	< .0001
Endometriosis	1,634	11.9	31,735	11.7	12,220	10.5	7,562	8.3	< .0001
Ovulatory dysfunction	1,707	12.5	30,727	11.3	15,633	13.4	22,153	24.2	< .0001
Tubal factor	1,551	11.3	35,576	13.1	22,122	18.9	18,795	20.5	< .0001
Uterine factor	605	4.4	12,877	4.7	6,527	5.6	5,241	5.7	< .0001
Unexplained	2,111	15.4	42,587	15.7	14,592	12.5	9,242	10.1	< .0001
Maximum serum FSH (mIU/mL)									
<5	1,895	13.9	38,657	14.2	18,309	15.7	18,070	19.7	< .0001
5.1–9.9	5,670	41.5	118,853	43.7	51,523	44.1	39,317	42.9	
≥10.0	3,053	22.3	53,771	19.8	19,845	17.0	11,711	12.8	
Missing	3,060	22.4	60,704	22.3	27,111	23.2	22,548	24.6	
No. of prior ART cycles									

	Underweight < 18.5 (kg/m^2)		Normal weight 18.5–24.9 (kg/m^2)		Overweight 25.0–29.9 (kg/m^2)		Obese >30 (kg/m^2)		
Patient characteristics	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**Chi square**
0	7,540	55.1	149,502	55.0	65,592	56.2	51,706	56.4	< .0001
1	2,673	19.5	54,107	19.9	23,367	20.0	19,133	20.9	
2+	3,464	25.3	68,332	25.1	27,810	23.8	20,792	22.7	
No. of prior pregnancies									
0	6,733	49.3	124,554	45.9	49,547	42.5	38,851	42.4	< .0001
1	3,632	26.6	72,717	26.8	30,775	26.4	23,933	26.1	
2+	3,293	24.1	74,388	27.4	36,327	31.1	28,756	31.4	
No. of prior spontaneous abortions									
0	10,023	73.7	190,476	70.4	78,972	67.9	61,383	67.2	< .0001
1	2,449	18.0	52,682	19.5	23,566	20.3	18,666	20.4	
2+	1,135	8.3	27,604	10.2	13,791	11.9	11,304	12.4	
No. of prior preterm births									
0	13,133	97.0	261,854	97.1	112,104	96.7	87,470	96.0	< .0001
1	379	2.8	7,161	2.7	3,448	3.0	3,228	3.5	
2+	33	0.2	760	0.3	430	0.4	400	0.4	
No. of prior full-term births									
0	10,162	74.7	200,843	74.1	84,184	72.3	67,360	73.7	< .0001
1	2,766	20.3	54,897	20.3	23,228	20.0	17,113	18.7	
2+	680	5.0	15,293	5.6	9,031	7.8	6,933	7.6	
Stimulation type									
None (natural cycle)	245	1.8	3,241	1.2	1,029	0.9	504	0.6	< .0001
Oral meds + gonadotropins	178	1.3	3,662	1.4	1,472	1.3	1,074	1.2	
Gonadotropins only (antagonist)	5,915	44.3	115,248	43.4	49,185	43.1	38,151	42.5	
Gonadotropins only (no suppression)	376	2.8	7,189	2.7	3,109	2.7	2,346	2.6	
Gonadotropins only (flare)	1,508	11.3	32,241	12.1	14,124	12.4	11,021	12.3	
Gonadotropins only (standard agonist)	5,138	38.5	104,016	39.2	45,341	39.7	36,668	40.9	
No. of oocytes retrieved									
0–4	1,880	15.2	33,757	13.8	14,487	13.9	11,661	14.3	< .0001
5–9	3,505	28.3	69,930	28.5	29,732	28.4	23,675	29.1	
>10	6,999	56.5	141,665	57.7	60,332	57.7	46,023	56.6	

	Underweight < 18.5 (kg/m^2)		Normal weight 18.5–24.9 (kg/m^2)		Overweight 25.0–29.9 (kg/m^2)		Obese >30 (kg/m^2)		
Patient characteristics	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**Chi square**
Ovarian hyperstimulation	190	1.4	3,570	1.3	1,343	1.1	896	1.0	< .0001
Used ICSI[a]	8,298	74.6	163,615	73.7	70,599	74.3	55,631	74.7	< .0001
Used assisted hatching[a]	4,671	42.0	93,362	42.0	39,901	42.0	31,889	42.8	.0013
No. of embryos transferred									
1	2,297	20.6	38,881	17.5	15,054	15.8	10,696	14.4	< .0001
2	5,860	52.7	117,945	53.1	50,745	53.4	40,139	53.9	
3	2,080	18.7	43,600	19.6	19,803	20.8	16,223	21.8	
>3	887	8.0	21,659	9.8	9,448	9.9	7,425	10.0	
Embryo stage at transfer[a,b]									
Days 2–3	6,060	54.5	122,554	55.2	52,818	55.6	42,498	57.1	< .0001
Days 5–6	4,817	43.3	94,847	42.7	40,186	42.3	30,261	40.6	
No. of supernumerary embryos cryopreserved[a]									
0	6,644	59.9	134,924	61.0	58,468	61.7	46,893	63.2	< .0001
1–2	1,834	16.5	36,493	16.5	15,349	16.2	11,714	15.8	
3–4	1,303	11.7	23,996	10.8	10,109	10.7	7,582	10.2	
5+	1,316	11.9	25,937	11.7	10,773	11.4	8,050	10.8	

Note: ART = assisted reproduction technology; FSH = follicle-stimulating hormone; ICSI = intracytoplasmic sperm injection; IVF = in vitro fertilization.

[a]Per noncancelled cycle resulting in transfer.

[b]Does not sum to 100% due to exclusion of transfers on days other than 2, 3, 5, or 6.

TABLE 2

ART cycle, transfer, and pregnancy outcomes by body mass index, fresh autologous IVF cycles, 2008–2013.

	Underweight			Obese			Normal weight (Reference)
Outcome	**n (%)**	**RR (95% Cl)**	**aRR (95% Cl)**	**n (%)**	**RR (95% Cl)**	**aRR (95% Cl)**	**n (%)**
Among cycles							
Cancellation	2,554 (18.7)	1.02 (0.98–1.05)	1.03 (0.99–1.07)	17,163 (18.7)	1.02 (1.00–1.04)	1.05 (1.03–1.07)	49,900 (18.4)
Among transfers							
Intrauterine pregnancy	4,969 (44.7)	0.97 (0.95–0.99)	0.97 (0.96–0.99)	31,252 (42.0)	0.91 (0.90–0.92)	0.94 (0.94–0.95)	102,227 (46.1)
Live birth (≥20 wk)	4,126 (37.2)	0.97 (0.95–0.99)	0.95 (0.93–0.98)	24,451 (32.9)	0.86 (0.85–0.87)	0.87 (0.86–0.88)	84,923 (38.3)
Among all pregnancies							
Miscarriage (<20 wk)	731 (14.8)	0.99 (0.92–1.06)	1.04 (0.98–1.11)	6,093 (19.6)	1.3 (1.27–1.34)	1.23 (1.20–1.26)	15,264 (15.0)
Among singleton pregnancies							
Low birth weight <2,500 g	345 (11.9)	1.38 (1.24–1.53)	1.39 (1.25–1.54)	1,888 (11.3)	1.30 (1.24–1.37)	1.26 (1.20–1.33)	5,134 (8.6)
Preterm delivery <37 wk	355 (12.0)	1.11 (1.00–1.22)	1.12 (1.01–1.23)	2,732 (16.0)	1.48 (1.42–1.54)	1.42 (1.36–1.48)	6,543 (10.8)
Among twin pregnancies							
Low birth weight <2,500 g	869 (80.3)	1.15 (1.11–1.18)	1.14 (1.10–1.17)	4,506 (67.1)	0.96 (0.94–0.98)	0.95 (0.94–0.97)	15,958 (70.1)
Preterm delivery <37 wk	675 (61.1)	1.04 (0.99–1.10)	1.04 (0.99–1.09)	4,282 (62.3)	1.06 (1.04–1.09)	1.06 (1.03–1.08)	13,574 (58.5)

Note: Adjusted models are controlled for age, number of prior pregnancies, cycle history, stimulation type, number of oocytes retrieved, use of intracytoplasmic sperm injection, use of assisted hatching, number of embryos transferred, stage of embryo at transfer, number of supernumerary embryos cryopreserved, and infertility diagnosis specifically diminished ovarian reserve, male factor infertility, endometriosis, ovulatory dysfunction, tubal factor infertility, uterine factor infertility, and unexplained. aRR = adjusted risk ratio; Cl = confidence interval; IVF = in vitro fertilization; RR = risk ratio.

TABLE 3

Pregnancy outcomes by degree of underweight body mass index, fresh IVF cycles, 2008–2013.

	Severe thinness < 16.0 kg/m^2			Moderate thinness 16.0–16.99 kg/m^2			Mild thinness 17.0–18.49 kg/m^2			Normal weight (Reference)
Outcome	**n (%)**	**RR (95% CI)**	**aRR (95% CI)**	**n (%)**	**RR (95% CI)**	**aRR (95% CI)**	**n (%)**	**RR (95% CI)**	**aRR (95% CI)**	**n (%)**
Among cycles										
Cancellation	87 (18.6)	1.02 (0.84–1.23)	1.03 (0.85–1.24)	265 (18.5)	1.01 (0.91–1.13)	1.05 (0.94–1.17)	2,202 (18.7)	1.02 (0.98–1.06)	1.03 (0.99–1.07)	49,900 (18.4)
Among transfers										
Intrauterine pregnancy	160 (42.1)	0.91 (0.81–1.03)	0.94 (0.85–1.03)	528 (45.4)	0.99 (0.92–1.05)	0.96 (0.92–1.01)	4,281 (44.7)	0.97 (0.95–0.99)	0.98 (0.96–0.99)	102,227 (46.1)
Live birth (≥20 wk)	136 (35.8)	0.93 (0.82–1.07)	0.91 (0.8–1.03)	441 (37.9)	0.99 (0.92–1.06)	0.92 (0.86–0.99)	3,549 (37.2)	0.97 (0.94–1.00)	0.96 (0.94–0.98)	84, 923 (38.3)
Among all pregnancies										
Miscarriage (<20 wk)	22 (13.8)	0.92 (0.62–1.35)	1.01 (0.70–1.48)	79 (15.0)	1.0 (0.82–1.23)	1.06 (0.86–1.29)	630 (14.8)	0.99 (0.92–1.06)	1.04 (0.97–1.12)	15,264 (15.0)
Among singleton pregnancies										
Low birth weight <2,500 g	13 (13.5)	1.57 (0.95–2.60)	1.58 (0.96–2.63)	50 (16.3)	1.89 (1.46–2.44)	1.93 (1.50–2.49)	282 (11.3)	1.31 (1.17–1.46)	1.32 (1.18–1.47)	5,134 (8.6)
Preterm delivery <37 wk	15 (15.5)	1.43 (0.90–2.28)	1.51 (0.95–2.41)	34 (10.6)	0.98 (0.72–1.35)	1.02 (0.74–1.40)	306 (12.0)	1.11 (1.00–1.23)	1.12 (1.00–1.24)	6,543 (10.8)
Among twin pregnancies										
Low birth weight <2,500 g	34 (91.9)	1.31 (1.19–1.44)	1.27 (1.16–1.39)	94 (84.7)	1.21 (1.12–1.31)	1.18 (1.09–1.27)	741 (79.3)	1.13 (1.09–1.17)	1.12 (1.09–1.16)	15,958 (70.1)
Preterm delivery < 37 wk	28 (73.7)	1.26 (1.04–1.52)	1.25 (1.04–1.51)	68 (59.7)	1.02 (0.88–1.19)	1.01 (0.87–1.18)	579 (60.8)	1.04 (0.99–1.09)	1.04 (0.98–1.09)	13,574 (58.5)

Note: aRR = adjusted risk ratio; CI = confidence interval; IVF = in vitro fertilization; RR = risk ratio.