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Does obesity affect embryo development and quality? A retrospective analysis

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Abstract

Research Question: Does high BMI impact embryo development and quality?

Design: This study compared morphokinetic parameters and developmental quality of embryos from Gonadotropin-releasing hormone (GnRH) antagonist, intra-cytoplasmic sperm injection (ICSI) cycles among four BMI groups (BMI <18.5, 18.5≤BMI<25, 25≤BMI<30, BMI≥30). Key parameters included time to pronucleus appearance (t2PN) and fading (tPNf), cleavage timings (t2-t8), time to morula and blastocyst formation, synchrony of the second cycle (S2), and duration of the second cycle (CC2). Additionally, the rate of top-quality day 3 and day 5 embryos was assessed.

Results: The analysis included 999 GnRH antagonist cycles and 2924 viable embryos. No statistically significant differences were found in the number of retrieved oocytes, oocyte maturation rate, fertilization rate, number of created embryos, discarded embryos rate, or pregnancy rate among the different BMI groups. However, notable differences were observed in certain morphokinetic parameters. Specifically, the obese group (BMI≥30) showed a shorter tPNf (p=0.03), a shorter second cell cycle division (CC2) (p < 0.001), and a shorter S3 (p=0.04) in the underweight group (BMI <18.5). The rate of top-quality blastocysts was higher in the underweight group compared to the higher BMI groups (p=0.01).

Conclusions: Obese women exhibited shorter pronuclear fading time and second cell cycle division, while underweight women showed a longer S3. The rate of top-quality blastocysts was lower in higher BMI groups, although these differences did not affect implantation or pregnancy rates.

Key words: Time lapse, Morphokinetic parameters, BMI, Obesity, overweight

Introduction

The World Health Organization defines Body Mass Index (BMI) as: "a simple index of weight-for-height that is commonly used to classify underweight BMI<18.5, normal 18.5≤BMI<25, overweight 25≤BMI<30 and obesity BMI≥30 in adults (World health prganization n.d.).

The prevalence of overweight and obesity continues to rise globally, at alarming rates in both children and adults, including women of childbearing age.

In the United States, the prevalence of obesity in adults increased from 30.5% in 1999–2000 to 42% in 2000–2020. (Aggarwal et al. 2023)

The link between obesity and metabolic syndrome has long been studied and proven. It can complicate pregnancies and their outcomes, and can have a detrimental effect on the health of the mother and the fetus (Linné 2004; José Bellver et al. 2006; Dokras et al. 2006).

In addition to the effect of obesity on the pregnancy itself, it has been previously shown that obese women are more prone to infertility problems (Rich‐Edwards et al. 1994; Hernáez et al. 2021), having lower pregnancy success rate naturally or with assisted reproductive technology (ART)(Crosignani et al. 1994; Zaadstra et al. 1993; van der Steeg et al. 2008; Kawwass et al. 2016; Provost et al. 2016; Supramaniam et al. 2018; Balsells, García-Patterson, and Corcoy 2016).

Obesity can cause ovulation dysfunction through peripheral aromatization in excess adipose tissue, dysregulating the hypothalamic – pituitary – ovarian axis. It may also cause insulin resistance and exacerbate polycystic ovary syndrome. (Broughton and Moley 2017). However, subfertility in obese patients is not linked merely with anovulation, as it also exists with obese ovulatory women(van der Steeg et al. 2008).

Some studies on ART treatments have shown poorer implantation, pregnancy, and live birth rates in obese women, however, embryo quality was not affected (Linné 2004; José Bellver et al. 2006, 2010; Lintsen et al. 2005; Péter Fedorcsák et al. 2004). Higher miscarriage rate was also documented(Péter Fedorcsák et al. 2004). Even after the transfer of an euploid embryo(Fabozzi et al. 2021; Boynukalin et al. 2021; Bakkensen, Strom, and Boots 2024; Cozzolino et al. 2021).

There was a progressive reduction in pregnancy, live birth, and cumulative pregnancy rates with each additional unit of BMI. As was found by Zhu et al "each unit increase in BMI predicted a 3% increase in the risk of infertility" (Bellver et al. 2010; Zhu et al. 2022)

Other studies however, showed no difference in ART outcomes in obese women except the need for higher doses of gonadotropins, longer treatments, and consequently lower numbers of oocytes during oocyte retrieval, and higher cancellation rates(Dokras et al. 2006; Dechaud et al. 2006; Wittemer et al. 2000).

Several hypotheses have been proposed to explain the impact of obesity on fertility: elevated levels of free fatty acids might exert harmful effects on reproductive tissues, potentially inducing chronic inflammation and cellular damage. (Broughton and Moley 2017), Adipokines, such as leptin, may also affect steroidogenesis, affecting the oocytes and embryo development (Broughton and Moley 2017)

Women with obesity undergoing IVF often exhibit changes in the follicular environment, characterized by elevated levels of insulin, triglycerides, and inflammatory markers such as lactate and C-reactive protein (CRP) in the follicular fluid (Robker et al. 2009).
In diet induced obesity mouse models, the ovaries demonstrate more apoptotic follicles and oocytes are smaller and less likely to be mature (Jungheim et al. 2010) these oocytes have high rates of meiotic aneuploidy with fragmented disorganized meiotic spindles and chromosomes not properly aligned on the metaphase plate. (Luzzo et al. 2012; José Bellver et al. 2007)the mitochondria is also altered, appears with more vacuoles and swelling, with clumping throughout the cytoplasm which can be caused by metabolic stress.

The endometrium and its environment may play a role in a lower implantation rate in obese women, most probably due to impaired stromal decidualization. This was tested in cycles with oocyte donation from healthy women and the ongoing pregnancy rates in obese women were significantly lower (José Bellver et al. 2007).
Examining whether lower fertility rates is linked to embryo quality, studies looked at the static embryo morphology comparing between obese and non- obese women showed no difference. (José Bellver et al. 2010)
Metabolomic analyses have identified reduced levels of saturated fatty acids in the culture media surrounding embryos from women with obesity. (Matorras et al. 2020; José Bellver et al. 2015) Additionally, Matorras et al. reported that oocytes from overweight and obese women contain lower concentrations of n-3 polyunsaturated fatty acids compared to those from women with a normal BMI.(Matorras et al. 2020).
Time-lapse monitoring (TLM) allows continuous observation of the developing embryo from the zygote to the blastocyst stage in time intervals for dynamic assessment of embryo morphokinetics. Studies on morphokinetics and BMI are scarce with conflicting results. One study on cleavage embryos found no differences in morphodynamics in obese women (J Bellver et al. 2013) while another found slower development(Bartolacci et al. 2019). Leary et al examined embryos reaching blastulation, embryos of obese women reached the morula stage faster, and the resulting blastocysts contained fewer cells – notably in the trophectoderm – in comparison with those from normal weight women. (Leary, Leese, and Sturmey 2015)

Comstock et al. reported decreased rates of blastocyst formation in the overweight and obese women(Comstock et al. 2015). While other studies showed no difference in the blastocyst formation rate between normal and obese women, although their embryos' development may be initially slower(José Bellver et al. 2021; José Bellver 2022).
The main aim of the present study, and due to conflicting results in the literature, is to assess the effect of women's BMI on embryo quality, assessed through an in-house model for embryo's morphokinetic parameters. The second aim is to test the relation between BMI and ART outcomes.

Materials and Methods

Study design- A retrospective cohort study evaluating the effect of BMI on embryos' morphokinetic parameters, and the quality of embryos derived from non-oocyte donor ICSI cycles during 2013-2022. Patients were divided into four groups based on four BMI categories: BMI <18.5, 18.5≤BMI<25, 25≤BMI<30, BMI≥30.

Institutional Review Board approval was obtained, study number 0034-21-CMC.
Patients were excluded if they were over 42 years of age, underwent standard IVF insemination (where oocyte maturation and fertilization timing couldn't be determined), had embryos cultured in standard incubators, or participated in preimplantation genetic testing (PGT) cycles. Embryos that were discarded or experienced early developmental arrest were also excluded from the final analysis.

Ovarian stimulation Protocol

All patients underwent a fixed antagonist protocol, beginning with daily gonadotropin injections from day 2–6 of menstruation. Gonadotropins included recombinant FSH (Gonal F, Merck KGaA, Darmstadt, Germany), recombinant FSH+LH (Pergoveris, Merck KGaA, Darmstadt, Germany), or urinary gonadotropins (hMG) (Menopur, Ferring, Saint-Prex, Switzerland). Cetrotide 0.25 mg (Merck KGaA) or Orgalutran 0.25 mg (Organon, Oss, Netherlands) was then administered daily until ovulation triggering. The gonadotropin dose was adjusted based on individual characteristics, ovarian reserve,

and previous response to stimulation. Follicular growth was monitored using transvaginal ultrasounds and serum hormone levels every 1–3 days.

Ovulation was triggered with either a GnRH agonist (Decapeptyl 0.2 mg, Ferring, Kiel, Germany), HCG (Ovitrelle 250 mcg, Merck, Switzerland), or a combination, depending on the risk for ovarian hyperstimulation syndrome (OHSS). Transvaginal ultrasound-guided oocyte retrieval occurred 36–38 hours post-trigger under general anesthesia. Mature oocytes were denuded and underwent intracytoplasmic sperm injection (ICSI). Embryos were cultured in time-lapse incubators (EmbryoScope™, Vitrolife) in individual wells.

Embryo transfers were performed on day 2, 3, or 5 based on patient age, embryo grade, and availability. Embryos were frozen in cases with a high risk of OHSS. Luteal support was provided using progesterone (vaginal or oral) until 8–10 weeks of viable pregnancy. A serum beta-hCG test was conducted 16 days after oocyte retrieval. Fresh embryo transfers were used to calculate pregnancy rates, while frozen embryos were excluded from this analysis. However, all embryos contributed to the evaluation of morphokinetic parameters.

The implantation rate was calculated as the ratio of gestational sacs to embryos transferred. Pregnancy loss was defined as the termination of a clinical pregnancy before 22 weeks of gestation. All outcomes, except pregnancy loss (calculated per clinical pregnancy), were assessed per cycle start.

Time-lapse embryo assessment

Morphokinetic parameters were measured using time-lapse technology. Early developmental events included the appearance and fading of pronuclei (PN), cleavage timings (zygote to 8 cells: t2-t8), and later stages such as morula formation and blastulation. The timing of events was expressed in hours post-ICSI. Parameters such as the duration of the second cell cycle (cc2 = t3–t2) and synchrony of the second division (s2 = t4–t3) were also evaluated.

Top-quality embryos, identified as having the highest implantation potential, were defined by meeting all the following parameters: for cleavage-stage embryos, tPNf

<24.08 hours, t2 <26.6 hours, S2 <0.9 hours, and t8 <56 hours post-insemination (hPi); for blastocysts, the criteria included t2 <26.6 hours, S2 <0.9 hours, t8 <56 hours, and tSB <96.6 hPi.

These parameters were established using a laboratory-adapted model based on known implantation data (KID) embryos. This in-house model was meticulously calibrated and validated, demonstrating improved accuracy for embryo selection. It has since been successfully integrated into routine practices within the IVF laboratory, offering additional predictive value for identifying embryos with high implantation potential (Blais et al. 2021).

Statistical analysis

We used SAS Software, Version 9.4 for statistical analysis. Continuous variables were presented as Mean±SD, and categorical variables as percentages (N, %). As the continuous variables were normally distributed, we used Student t-test to compare continuous variables. The Kolmogorov Smirnov test was used to asses normality of distributions. Proportions were compared using Chi-Square or Fisher's exact when appropriate. P values of less than 0.05 were considered statistically significant. Univariate analysis was used to compare baseline and treatment characteristics, as well as morphokinetic parameters and optimal cell divisions parameters, between the study and the control group. Multivariate logistic regression analysis was performed to evaluate the relationship between the variables of interest and the outcomes of the study i.e. the quality of embryos. This analysis was conducted at the end of the study to adjust for potential confounding factors and to determine the independent effects of each variable on the outcome measures.

Results

999 GnRH antagonist cycles were included in the study and were divided into four groups based on the patients' BMI.

All groups were comparable in terms of age, gravidity, estradiol level during ovum pick up, the main infertility diagnosis (male factor, tubal factor, anovulation, unexplained infertility), type of gonadotropin and the type of trigger used.

However, the basal FSH and LH levels were lower in women with higher BMI, while these women needed higher doses of gonadotropins during their IVF treatments (Table 1).

As for the IVF treatments results, BMI had no effect on the number of retrieved oocytes, oocyte maturation rate, fertilization rate, number of created embryos, or the rate of discarded embryos. (Table 1)

The endometrium was thicker at the time of OPU in the higher BMI group.

There were no differences between the groups in terms of positive HCG test, implantation rate, live birth rate or miscarriage rate. (Table 1)

2924 viable embryos were analyzed for morphokinetic parameters and developmental quality as shown in Table 2.

The only morphokinetic parameters that differed between the groups were a shorter tPNf in the obese group ($p=0.03$), and a shorter second cell cycle division (cc2) ($p<0.001$), and a shorter S3 (p-0.04) in the underweight group. In other words, a shorter time for pronuclear fading, a longer resting phase between the 2-3 cell stage, and a longer time to reach the third cell cycle stage in obese women.

The rate of top-quality blastocysts was higher in the underweight group compared to the higher BMI groups ($p=0.01$).

In a sub-analysis comparing the underweight group (BMI < 18.5) to each of the other BMI groups, a consistently shorter time to CC2 was observed in underweight women. However, a shorter time to pronuclear fading, along with a longer time to CC2 and S3, was observed specifically in the BMI ≥ 30 group. (Tables 2a-2c).

The group with $25 \leq$ BMI < 30 had a significantly lower rate of top-quality blastocysts compared to the group with BMI < 18.5 ($p = 0.002$) and the group with $18.5 \leq$ BMI < 25 ($p = 0.03$). However, this difference did not reach statistical significance when compared with the BMI ≥ 30 group ($p = 0.09$).

Table 3 and 4 summarize the multivariate logistic regression analysis for top quality embryos day 3 and day 5. The analysis indicates that while some factors like BMI and age show trends toward influencing the likelihood of top-quality embryos, none of the variables reached statistical significance, suggesting that their impact might be minimal or affected by variability in the data.

Discussion

In our study, we evaluated the impact of BMI on embryo quality and found that elevated BMI can influence several morphokinetic parameters of embryos. Specifically, we observed a shorter time to pronuclear fading in women with higher BMI, along with a longer resting phase between the 2-3 cell stage (CC2) and a prolonged duration to reach the third cell cycle stage. A sub-analysis comparing only the underweight group to each of the other groups showed similar results between the obese and underweight group. Our findings agree with those of Bellver et al., who examined embryos from ICSI cycles involving 2,882 women, categorized into 140 underweight, 1,989 normal weight, 548 overweight, and 145 obese individuals. Their study reported slower early-phase embryo development in obese women, with this delay resolving by the blastulation stage. Additionally, no significant differences in blastocyst quality were observed across the different BMI groups. (José Bellver et al. 2021).

We found a higher rate of top-quality blastocysts in the underweight group compared to the higher BMI groups ($p=0.01$). The group with $25 \leq BMI < 30$ had a significantly lower rate of top-quality blastocysts compared to lower BMI groups.

Similar to our findings, Comstock et al. reported poor embryo progress with decreased rates of blastocyst formation in the overweight and obese group (57.2 versus 43.6 %, $p < 0.007$). On the other hand, Kim et al presented contrasting results with higher blastocyst formation rate in the obese group.(Comstock et al. 2015)

Our study found that women with higher BMI required larger doses of gonadotropins to achieve similar stimulation outcomes compared to women with lower BMI. However, when given higher gonadotropin doses, elevated BMI did not impact the number of oocytes retrieved, oocyte maturation rate, fertilization rate, number of embryos created, embryo discard rate, pregnancy rate, live birth rate, or miscarriage rate. These findings support the conclusions of Ben-Haroush et al. and Dechaud et al. (Dechaud et al., 2006; Ben-Haroush et al., 2018).

Some studies on ART treatments have shown poorer implantation, pregnancy, and live birth rates in obese women (Linné 2004; José Bellver et al. 2006, 2010; Lintsen et al. 2005; Péter Fedorcsák et al. 2004; Provost et al. 2016; Kawwass et al. 2016) and higher miscarriage rate was also documented(P Fedorcsák et al. 2000; Cozzolino et al. 2021). Cozzolino et al

examined 3,480 cycles of in vitro fertilization with preimplantation genetic testing for aneuploidy (PGT-A) in the blastocyst stage and euploid embryos and found higher clinical miscarriage rate in higher BMI patients.(Cozzolino et al. 2021)
Bellver et al found a progressive reduction in Pregnancy, live birth, and cumulative pregnancy rates with each additional unit of BMI (José Bellver et al. 2010).
In a systematic review and meta-analysis that included 49 studies, it was found that overweight or obese women (BMI ≥ 25 kg/m^2) have a statistically significant reduction in live birth rates, with an odds ratio (OR) of 0.81 (95% CI: 0.74–0.89, $p < 0.00001$) compared to women with a normal BMI. Furthermore, women with a BMI ≥ 30 kg/m^2 experience a higher rate of miscarriages, with an odds ratio of 1.52 (95% CI: 1.28–1.81, $p < 0.00001$).(Supramaniam et al. 2018)

Other studies however, showed no difference in ART outcomes in obese women. Dechaud et al found similar implantation rates, pregnancy rates and cancellation rates in all BMI groups. However, women with BMI >30 needed higher doses of recombinant FSH in the long protocol treatments (Dechaud et al. 2006; Wittemer et al. 2000). Wittemer et al. found similar results with more gonadotropins needed in higher BMI, however, with lower number of oocytes retrieved in BMI >25 in both long and short protocols (Wittemer et al. 2000; Robker et al. 2009).
It is important to note that underweight may also have adverse effects based on some studies, which contrast to our findings. A meta-analysis by Balsells et al found that maternal underweight is associated with a slightly increased risk of clinical miscarriage, comparable to that of overweight women, but lower than the risk observed in obesity (Balsells, García-Patterson, and Corcoy 2016). Cai et al. demonstrated that low BMI is associated with reduced live birth rates and increased miscarriage rates compared to normal weight (Cai et al. 2017). Additionally, Kawwass et al. reported adverse pregnancy outcomes for both underweight and obese women (Kawwass et al. 2016).

Considering our results, it is unclear what truly is the clinical impact of the differences found in the morphokinetic parameters between the groups especially since the clinical parameters, specifically the pregnancy rate, implantation rate, liveborn rate and miscarriage rates, were unaffected.

The strengths of the study being a single center study, using the same time lapse parameters, and an in-house model, under standardized laboratory conditions. Only GnRH antagonist protocol ICSI cycles were included in the to control fertilization time for standardization purposes.

The main limitations of the study include its retrospective nature, which introduces the inherent challenges of retrospective data retrieval. Additionally, the relatively small sample sizes in each BMI group, especially for extreme BMI values, may influence the results. Euploidy was not assessed through biopsy; while confirming euploidy could strengthen the association between BMI and embryo quality, the impact of biopsy on embryo quality remains debatable. Although the number of embryos transferred and their developmental stage were not standardized across patients, these factors were consistent between groups.

Conclusion:

Overall, morphokinetic parameters and embryo quality, as evaluated by time-lapse monitoring, appear unaffected by maternal weight, even in extreme BMI subgroups. The slight differences observed in obese women do not seem to have clinical significance, as they did not impact implantation or pregnancy rates. Given our findings and the conflicting results in the literature, larger-scale studies are needed to further clarify these effects.

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Table 1 - Demographic parameters and treatment characteristics

	BMI<18.5 (N=62)	18.5≤BMI<25 (N=445)	25≤BMI<30 (N=265)	BMI≥30 (N=227)	P
Age	34.0±5.3	33.7±5.8	34.5±6.0	34.1±5.6	0.2
BMI	17.2±0.8	21.6±1.7	26.7±1.4	33.6±3.6	<0.001
Basal FSH	8.9±3.5	7.8±2.7	7.4±2.5	6.8±2.4	<0.001
Basal LH	5.8±2.6	5.6±2.5	5.6±4.4	4.8±2.6	<0.001
Gravidity	0.6±0.7	0.8±1.0	0.9±1.2	0.9±1.2	0.1
Gonadotropin dose	2102.3±1154.6	2011.8±950.3	2283.0±1085.9	2430.9±975.4	<0.001
Endometrial thickness (mm)	9.6±2.0	9.7±2.2	10.2±2.3	10.0±2.5	0.01
Estradiol at OPU	6135.5±3076	6662.3±4713.9	5954.7±4083.1	5702.6±3487.5	0.05
Oocytes aspirated	10.1±5.4	10.5±6.7	10.3±6.6	10.7±6.9	0.9
Maturation rate	0.8±0.2	0.8±0.2	0.8±0.2	0.7±0.2	0.4
2PN fertilization	5.2±4.6	5.2±3.5	5.0±3.2	5.0±3.3	0.9
Created Embryos	3.0±2.0	3.1±1.8	2.9±1.8	3.1±1.9	0.5
Rate of discarded embryos	0.4±0.2	0.3±0.3	0.4±0.3	0.3±0.3	0.09
Pregnancy rate (positive HCG)	52.3%	46.8%	48.9%	54.8%	0.4
Implantation rate	19.3%	16.3%	13.8%	17.4%	0.4
Miscarriage rate	12.5%	24.1%	17.4%	12.5%	0.6
Live birth rate	14.5%	11.8%	11.1%	13.4%	0.4

Table 2 – The association between BMI groups and embryo morphokinetic parameters					
Morphokinetic parameters (hours)	**BMI<18.5 (N=178)**	**18.5≤BMI<25 (N=1330)**	**25≤BMI<30 (N=734)**	**BMI≥30 (N=682)**	**P**
TPB2	3.3±1.1	3.5±1.7	3.5±1.1	3.5±1.3	0.3
TPNf	24.4±3.1	24.3±3.2	24.2±3.1	23.9±3.0	0.03
T2	27.7±6.8	27.1±4.5	26.8±3.4	26.8±4.7	0.1
T3	39.0±5.9	38.8±4.7	38.7±4.2	38.6±4.6	0.7
T4	40.0±6.1	39.8±5	39.7±4.4	39.8±5.2	0.8
T5	52.3±6.8	51.9±6.6	52.0±6.5	52.0±6.6	0.7
T6	53.9±6.3	53.8±5.9	54.0±5.9	53.8±6.4	0.6
T7	55.6±7	55.8±6.8	56.0±6.5	55.6±7.0	0.4
T8	57.1±7.5	57.6±7.5	57.8±7.6	57.7±7.7	0.7
CC2:T3-T2	11.3±2.7	11.7±2.2	11.9±2.3	11.8±2.5	0.0002
S2:T4-T3	1.0±1.9	1.1±2.1	1.0±2.0	1.2±2.7	0.9
S3:T8-T5	5.3±5.4	5.8±5.6	5.9±6.1	5.9±5.5	0.04
TSB	97.7±9.5	98.4±8.1	99.0±7.9	98.3±8.3	0.5
Top quality embryos day 3 (rate)	(N=142) 27.5%	(N=1043) 25.4%	(N=593) 23.9%	(N=560) 23.7%	0.7
Top quality embryos day 5 (rate)	(N=101) 25.7%	(N=549) 17.6%	(N=300) 12%	(N=269) 17.1%	0.01

Table 2a : BMI<18.5 VS 18.5≤BMI<25			
Morphokinetic parameters (hours)	**BMI<18.5 (N=178)**	**18.5≤BMI<25 (N=1330)**	**P**
TPB2	3.3±1.1	3.5±1.7	0.9
TPNf	24.4±3.1	24.3±3.2	0.5
T2	27.7±6.8	27.1±4.5	0.5
T3	39.0±5.9	38.8±4.7	0.9
T4	40.0±6.1	39.8±5	0.8
T5	52.3±6.8	51.9±6.6	0.6
T6	53.9±6.3	53.8±5.9	0.7
T7	55.6±7	55.8±6.8	0.9
T8	57.1±7.5	57.6±7.5	0.6
CC2:T3-T2	11.3±2.7	11.7±2.2	0.02

S2:T4-T3	1.0±1.9	1.1±2.1	0.9
S3:T8-T5	5.3±5.4	5.8±5.6	0.2
TSB	97.7±9.5	98.4±8.1	0.4
Top quality embryos day 3	(N=142) 27.5%	(N=1043) 25.4%	0.6
Top quality embryos day 5	(N=101) 25.7%	(N=549) 17.6%	0.07

Table 2b : BMI<18.5 VS 25≤BMI<30

Morphokinetic parameters (hours)	**BMI<18.5 (N=178)**	**25≤BMI<30 (N=734)**	**P**
TPB2	3.3±1.1	3.5±1.1	0.3
TPNf	24.4±3.1	24.2±3.1	0.3
T2	27.7±6.8	26.8±3.4	0.3
T3	39.0±5.9	38.7±4.2	0.7
T4	40.0±6.1	39.7±4.4	0.9
T5	52.3±6.8	52.0±6.5	0.9
T6	53.9±6.3	54.0±5.9	0.8
T7	55.6±7	56.0±6.5	0.4
T8	57.1±7.5	57.8±7.6	0.3
CC2:T3-T2	11.3±2.7	11.9±2.3	0.0002
S2:T4-T3	1.0±1.9	1.0±2.0	0.8
S3:T8-T5	5.3±5.4	5.9±6.1	0.4
TSB	97.7±9.5	99.0±7.9	0.2
Top quality embryos day 3	(N=142) 27.5%	(N=593) 23.9%	0.4
Top quality embryos day 5	(N=101) 25.7%	(N=300) 12%	0.002

Table 2c : BMI<18.5 VS BMI≥30

	BMI<18.5 (N=178)	**BMI≥30 (N=682)**	**P**
TPB2	3.3±1.1	3.5±1.3	0.5
TPNf	24.4±3.1	23.9±3.0	0.03

T2	27.7±6.8	26.8±4.7	0.08
T3	39.0±5.9	38.6±4.6	0.7
T4	40.0±6.1	39.8±5.2	0.6
T5	52.3±6.8	52.0±6.6	0.7
T6	53.9±6.3	53.8±6.4	0.8
T7	55.6±7	55.6±7.0	0.9
T8	57.1±7.5	57.7±7.7	0.4
CC2:T3-T2	11.3±2.7	11.8±2.5	0.002
S2:T4-T3	1.0±1.9	1.2±2.7	0.9
S3:T8-T5	5.3±5.4	5.9±5.5	0.02
TSB	97.7±9.5	98.3±8.3	0.5
Top quality embryos day 3	(N=142) 27.5%	(N=560) 23.7%	0.4
Top quality embryos day 5	(N=101) 25.7%	(N=269) 17.1%	0.07

Table 3 - Logistic Regression Analysis Results for predicting day 3 Top quality embryos

Variable	Estimate (β)	Standard Error (SE)	Wald Chi-Square	p-value	Odds Ratio (OR)	95% Confidence Interval for OR
BMI category						
- 18.5-<25 (Ref.)						
- 25-<30	-0.1440	0.2108	0.4665	0.4946	0.866	0.573 to 1.309
- <18.5	-0.2682	0.4440	0.3647	0.5459	0.765	0.320 to 1.826
- =>30	—	—	—	—	—	—
Age	-0.0192	0.0104	3.4156	0.0646	0.981	0.961 to 1.001
BMI	-0.0311	0.0247	1.5943	0.2067	0.969	0.924 to 1.017
Oocytes Aspirated	0.00145	0.00797	0.0330	0.8559	1.001	0.986 to 1.017
E2 at OPU	7.7E-6	0.000012	0.4029	0.5256	1.000	1.000 to 1.000
Gonadotropins	0.1209	0.1689	0.5120	0.4743	1.128	0.810 to 1.571

Table 4 - Logistic Regression Analysis Results for predicting day 5 Top quality embryos						
Variable	**Estimate (β)**	**Standard Error (SE)**	**Wald Chi-Square**	**p-value**	**Odds Ratio (OR)**	**95% Confidence Interval for OR**
BMI Category						
- 18.5-<25 (Ref.)	—	—	—	—	—	—
- 25-<30	-0.2220	0.3757	0.3491	0.5546	0.801	0.383 to 1.673
- <18.5	0.9638	0.7425	1.6851	0.1943	2.622	0.612 to 11.235
- =>30	—	—	—	—	—	—
Age	-0.0328	0.0176	3.4761	0.0623	0.968	0.935 to 1.002
BMI	0.0246	0.0429	0.3294	0.5660	1.025	0.942 to 1.115
Oocytes Aspirated	0.00603	0.0114	0.2794	0.5971	1.006	0.984 to 1.029
E2 at OPU	0.00001	0.000016	0.3738	0.5410	1.000	1.000 to 1.000
Gonadotropins	0.3024	0.2935	1.0614	0.3029	1.353	0.761 to 2.405

Key message

Obese women exhibited a shorter time for pronuclear fading and the second cell cycle division, while underweight women showed a longer S3. The rate of top-quality blastocysts was lower in higher BMI groups. However, these differences do not seem to affect implantation or pregnancy rates.

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