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FETAL GROWTH ABNORMALITIES IN OVERWEIGHT AND OBESE PREGNANT WOMEN: A STUDY AMONG BULGARIAN PREGNANT WOMEN

I. Hristova[1], E. Naseva[2], M.Yunakova[1]

[1]University Obstetrics and Gynaecology Hospital "Maichin Dom", Medical University – Sofia, Bulgaria
[2]Department of Health Management and Health Economics, Faculty of Public Health
"Prof. Tzecomir Vodenitcharov, MD, DSc", Medical University – Sofia, Bulgaria

Abstract. *A small for gestational age (SGA) newborn is a clinical finding during pregnancy resulting from various underlying conditions, such as placental pathology, preeclampsia, gestational diabetes, and maternal obesity. SGA is usually suspected when the fetal weight falls below the 10th centile for gestational age and must be distinguished from fetal growth restriction.* ***Aims:*** *To evaluate the influence of prepregnancy BMI on the prevalence of SGA and fetal macrosomia at term in singleton pregnancies within a non-selected population of Bulgarian women.* ***Materials and Methods:*** *A total of 199 overweight (BMI 25-29.9 kg/m²) and 198 obese (BMI ≥ 30 kg/m²) women were compared with a control group of 459 women with normal prepregnancy BMI (18.5-24.9 kg/m²). Birthweight categories included: normal for gestational age (10th-90th percentile), low for gestational age (below 10th percentile), and large for gestational age (above 90th percentile). SGA was further classified into moderate (3rd-10th percentile) and severe (below 3rd percentile).* ***Results:*** *Results indicated a statistically significant lower percentage of normal birth weight in the overweight group (76.88%) compared to the control group (82.57%, p = 0.044). Overweight women had a higher incidence of large for gestational age newborns (17.59%) compared to the control group (10%, p = 0.03). No significant differences were found in low birthweight or moderate SGA between groups. However, severe SGA was significantly less common in the overweight group (1%) compared to the obese group (3.54%, p = 0.0045). Macrosomia (birth weight ≥ 4000 g) was more prevalent in overweight women (10.3%) than in those with a normal BMI (5.82%, p = 0.037). Relative risk analysis showed increased risks for large for gestational age and macrosomia in overweight and obese women.* ***Conclusions:*** *The study emphasizes the importance of targeted interventions to control and regulate maternal weight to minimize the risk of adverse fetal and neonatal outcomes.*

Key words: *macrosomia, small for gestational age, pregnancy, maternal weight, body mass index, overweight, obesity, term pregnancy*

Corresponding author: *Iana Hristova, University Obstetrics and Gynaecology Hospital "Maichin Dom", Medical University – Sofia, Bulgaria, email: iana.hristova06@gmail.com*

ORCID: *0009-0009-4652-4778 – Iana Hristova*

ORCID: *0000-0002-1282-8441 – Emilia Naseva*

ORCID: *0000-0001-9397-3466 – Mariya Yunakova*

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INTRODUCTION

Pregnancies, in which adverse intrauterine conditions hinder the fetus from reaching its growth potential, represent a high-risk group for whom perinatal complications can be prevented through prenatal identification. Following prematurity, intrauterine fetal growth restriction (FGR) is the second leading cause of perinatal mortality. Preventing certain perinatal complications that result in adverse outcomes in cases of FGR is achievable through the proper identification and management of these conditions during pregnancy [1, 2]. FGR depends on various factors, including genetic predisposition, vascular placental causes, maternal ethnicity, environmental influences, chromosomal defects, genetic abnormalities, and fetal infections [1-3].

SGA is a term that includes constitutionally small babies with normal fetal Dopplers throughout pregnancy, as well as those with FGR, where smaller size is combined with pathological Doppler changes in fetal vessels such as the umbilical arteries, ductus venosus, and middle cerebral artery. A substantial amount of evidence indicates that being overweight or obese is associated with adverse health effects, with a dose effect for BMI noted. Risk factors for SGA include maternal BMI below 20 or above 25. The diagnosis of SGA relies on accurate information about the actual gestational age (GA) and data from ultrasonographic biometry conducted at earlier stages of pregnancy, specifically at 11-14 weeks' gestation or during the second trimester. Routinely measured ultrasound parameters in the second trimester are biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) [2-5]. The AC most accurately corresponds to the probable weight. The sensitivity of this indicator in diagnosing FGR ranges from 50 to 60%. BPD and HC, along with FL, are less strongly linked to the accurate estimation of probable fetal weight. Not only are individual parameters evaluated, but also the ratios between them – the so-called "ponderal indices", which reflect the proportions of different parts of the fetal body. Changes in ponderal indices in FGR are associated with placental development; in these cases, the retardation was asymmetric, with the earliest and most severe delay observed in the rise of abdominal circumference (AC). The presence of oligohydramnios is a common finding in FGR associated with placental insufficiency, occurring in approximately two-thirds of cases. FGR is categorized into moderate, corresponding to the weight of a newborn or sonographically estimated fetal weight between the 3rd and 10th percentiles for the corresponding gestational age, and severe, which pertains to weights below the 3rd percentile, according to the Fenton curves. According to the period of manifestation, the FGR is classified as early, requiring delivery before 34 weeks, and late, requiring delivery after 34 weeks [3-6].

To assess the etiology and pathogenesis of FGR, Doppler blood flow studies are conducted on certain fetal vessels and the uterine arteries of the pregnant woman. In FGR of placental origin, there is normal fetal morphology and asymmetric growth retardation, coupled with oligohydramnios and an abnormal diastolic index (DI) in the umbilical and uterine arteries. Doppler examination of the fetal umbilical arteries additionally enables the identification of fetuses with FGR and high perinatal risk. Umbilical artery indices above the 90th or 95th percentile are regarded as elevated [3-5]. Elevated umbilical artery DIs are associated with lower birth weight, earlier gestational age at delivery, a higher incidence of caesarean sections due to fetal distress, lower Apgar scores, more frequent and prolonged stays in neonatal intensive care units (NICU), and an increased incidence of perinatal mortality [4, 7].

MATERIALS AND METHODS

The fetal birthweight was analyzed in 199 singleton term pregnancies with maternal overweight (BMI 25-29.9 kg/m²) – Group 1 (G-1) – and 198 with maternal obesity (BMI ≥ 30 kg/m²) – Group 2 (G-2). Parturients were grouped according to their prepregnancy BMI. The proportion of newborns was evaluated for: 1) normal for gestational age birthweight (between the 10th and 90th centile); 2) low for gestational age birthweight (less than the 10th centile); 3) large for gestational age birthweight (greater than the 90th centile). SGA newborns were further analyzed according to severity and classified into two subgroups – those with birthweight between the 3rd and 10th centiles and those with birthweight below the 3rd centile.

All indicators for overweight and obese groups were compared individually with those from the control group of 459 parturients with a normal prepregnancy BMI (18.5-24.9 kg/m²) (CG), as well as amongst themselves.

The relative proportion of macrosomic newborns at term (≥ 4000 g) from 154 overweight parturients was also analyzed, categorized as Subgroup-1 (SG-1), alongside 138 obese parturients as Subgroup-2 (SG-2), and from 379 with a normal prepregnancy BMI, as the control subgroup (CSubG). Analysis was performed for the subgroups overall and separately for male and female fetuses.

Pregnancies were singleton, and the fetuses/newborns had no structural abnormalities, with accurate

data on gestational age at delivery available. Fenton curves tailored to the gestational age and sex of the newborn, applied in the University Obstetrics and Gynecology Hospital "Maichin Dom", were used to categorize the newborn's weight. The design of our study was retrospective, and Doppler studies were not available in all cases. Because of this, we have analyzed cases of SGA fetuses and babies in general without being able to separate the cases with growth restriction.

Statistical Analysis

The Chi-square test and Fisher's exact test were used to assess the statistical significance of differences. The latter was applied to a small number of cases in the sample (N ≤ 5). Differences were considered statistically significant at p values < 0.05. IBM SPSS ver. 29 was used.

RESULTS

Fetal birthweight in overweight, obese, and normal prepregnancy BMI women

The comparison of fetal birth weight among the three groups is presented in Table 1. The percentage of newborns with normal birth weight for gestational age in the overweight group (G-1) is lower (76.88%) than that in the normal BMI group (82.57%), and this difference is statistically significant (p = 0.044). The percentages of low-birth-weight infants in G-1 and CG were 5.52% and 7.4%, respectively; the difference was not statistically significant (p > 0.05). Among the overweight pregnant women, 4.52% had a moderate SGA, and 1% had severe SGA. In the normal prepregnancy BMI CG, the percentages were 5.23% and 2.18%, respectively, with no statistically significant difference between the two groups. Overweight women delivered large for gestational age (LGA) newborns in 17.59% of cases, while those with a normal prepregnancy BMI had LGA newborns in 10% of cases; the difference between these two groups was statistically significant (p = 0.03).

When comparing the obese and normal BMI groups, we identified some significant differences. The relative proportion of newborns with normal birth weight in obese women was 77.77%, whereas in those with normal BMI, it was 82.57%, with no statistically significant difference (p = 0.075) (Table 1). Overall, low birth weight infants constituted 7.07% in the obese group and 7.4% in the normal BMI group, with no statistically significant difference (p > 0.05). The percentage of newborns with moderate SGA in the obese group was 3.54%, which was not significantly different from that in the normal BMI group (5.23%, p > 0.05). In the obese group, the relative proportion of newborns with severe SGA (3.54%) was comparable to that in the control group (2.18%), with no statistically significant difference (p > 0.05). Pregnant women with obesity in 15.15% of cases gave birth to large for gestational age newborns, and the percentage is significantly higher compared to the normal BMI group – 10% (p = 0.03).

In the overweight and obese groups (Table 1), there were no statistically significant differences in the relative proportions of newborns with normal and high birth weights, which were 76.88% and 77.77%, respectively, and 17.58% and 15.15%, respectively (p > 0.05). There was also no significant difference in the incidence of retardation, which was observed in 7.07% of the obese group and 5.52% of the normal weight group (p > 0.05). In the overweight group (G-1), the percentages of cases with both the moderate and severe retardation were identical – 3.54%.

Table 1. Fetal birthweight in overweight, obese women and women with normal prepregnancy BMI

	Overweight (BMI 25-29.9 kg/m²) N = 199	**p-value G-1/CG**	**Normal BMI (18.5-24.9 kg/m²) N = 459**	**p-value G-2/CG**	**Obesity (BMI ≥30 kg/m²) N = 198**	**p-value G-1/G-2**
Normal for GA W – 10th-90th c	153/199 (76.88%)	0.044*	379/459 (82.57%)	>0.05	154/198 (77.77%)	>0.05
SGA W <10thc	11/199 (5.52%)	>0.05	34/459 (7.4%)	>0.05	14/198 (7.07%)	>0.05
Moderate SGA W – 3-10th c	9/199 (4.52%)	>0.05	24/459 (5.23%)	>0.05	7/198 (3.54%)	>0.05
Severe SGA – W <3th c	2/199 (1%)	>0.05	10/459 (2.18%)	>0.05	7/198 (3.54%)	0.0045*
LGA – W >90th c	35/199 (17.58%)	0.003*	46/459 (10%)	0.03*	30/198 (15.15%)	>0.05

Abbreviations and symbols: BMI – body mass index; c – percentile; CG – control group (pregnant women with normal BMI); G-1 – study group 1 (overweight pregnant women); G-2 – study group 2 (obese pregnant women); GA – gestational age; LGA – large for the gestational age; SGA – small for the gestational age; W – weight (of the newborn); * – statistically significant difference.

The difference between the overweight and moderate SGA groups was not statistically significant; however, in cases of neonatal birthweight below the 3rd centile, it was significant, with the difference being notably less in the overweight group (1%), p = 0.045.

Severity of SGA among normal weight, overweight, and obese pregnant women

A separate analysis of the cases with SGA revealed that in the overweight group, the percentage of moderate SGA was 81.81%, while that of severe SGA was 18.18%. The corresponding percentages in the normal weight group were 70.59% and 29.41%. The differences in these two indicators were not statistically significant (p > 0.05) (Table 2).

A comparison of the obese and normal-weight pregnant groups revealed that in the former, the relative proportion of severe SGA to SGA-only cases was 50%, which was higher than in the control group (29.41%). However, the difference was not statistically significant. Notably, the proportion of moderate SGA in the obese group (50%) is lower than in the group with a normal BMI (70.59%), but this difference was also not statistically significant (p > 0.05). A comparison between the overweight and obese groups shows that the former is dominated by cases with moderate retardation (81.81%), which are more frequent than those in the obese group (50%). The difference in this indicator holds marginal statistical significance, with a p-value of 0.049. Conversely, cases of severe SGA were more prevalent in the obese group (50%) compared to the overweight group (18.18%), and this difference was also statistically significant (p < 0.049) (Table 2).

Macrosomia at term in overweight and obese pregnant women

The relative proportion of newborns with macrosomia at term – birthweight ≥4000 g – in 154 overweight pregnant women was analyzed (SG-1) and in 138 obese pregnant women (SG-2). A comparison was made with 379 pregnant women with a normal pre-pregnancy BMI. The results are presented in Table 3.

Overweight pregnant women, on average, gave birth to term newborns with macrosomia in 10.3% of cases, while those with normal weight gave birth to newborns with macrosomia in 5.82% of cases. The difference was statistically significant (p = 0.037), as shown in Table 3. For male newborns, the respective percentages were 15.6% and 9.9%, with the difference not being statistically significant. The proportion of female newborns in the overweight group with macrosomia was 3.9% compared to 1.1% in the normal-weight control subgroup. The difference between these two indicators was of marginal statistical significance (p = 0.069).

On average, 7.24% of pregnant women with obesity give birth to macrosomic newborns at term, compared

Table 2. SGA according to severity among the normal-weight, overweight, and obese pregnant women

	Overweight (BMI 25-29.9 kg/m^2) N = 11	**p-value G-1/CG**	**Normal BMI (18.5-24.9 kg/m^2) N = 34**	**p-value G-2/CG**	**Obesity (BMI ≥30 kg/m^2) N = 14**	**p-value G-1/G-2**
Moderate SGA – W 3-10th c	9/11 (81.81%)	>0.05	24/34 (70.59%)	>0.05	7/14 (50%)	<0.05*
Severe SGA –W <3th c	2/11 (18.18 %)	>0.05	10/34 (29.41 %)	>0.05	7/14 (50%)	<0.049*

Abbreviations and symbols: BMI – body mass index; c – percentile; CG – control group; G-1 – study group-1 (overweight pregnant women); G-2 – study group-2 (obese pregnant women); SGA – small for the gestational age; W – weight (of the newborn); * – statistically significant difference between the study groups

Table 3. Macrosomia at term in overweight, obese, and normal BMI pregnant women

	Overweight (BMI ≥25-29.9 kg/m^2)	**p-value SG-1/CsG**	**Normal BMI (18.5-24.9 kg/m^2)**	**p-value SG-2/CsG**	**Obesity (BMI ≥30 kg/m^2)**	**p-value SG-1/SG-2**
All newborns	N = 154 15/154 (10.3%)	p<0.05*	N = 378 22/379 (5.82%)	>0.05	N = 138 10/138 (7.24%)	>0.05
Newborns –males	N = 77 12/77 (15.6%)	>0.05	N = 202 20/202 (9.9%)	>0.05	N = 77 6/77 (7.8%)	p = 0.066м
Newborns –females	N = 77 3/77 (3.9%)	0.069м	N = 176 2/176 (1.1%*)	0.009*	N = 61 4/61 (6.6%)	p<0.05*

Abbreviations and symbols: CsG – control subgroup; м – marginal statistical significance of differences; SG-1 – study subgroup-1 (overweight pregnant women); SG-2 – study subgroup-2 (obese pregnant women); * – statistically significant difference

to 5.8% of those with normal weight. The difference is not statistically significant. For male newborns, the corresponding percentages were 7.8% and 9.9%, and the difference was likewise not statistically significant. However, newborns with female macrosomia in the obese group were 6.6%, which was significantly higher compared to the normal weight group at 1.1% (p = 0.009) (Table 3).

Comparison between the overweight and obese groups showed no significant differences in the percentages of newborns with macrosomia at term, overall (10.3% and 7.24%, respectively) and in those of the female sex (3.9% and 6.6%), p>0.05. Among the male newborns, the difference between the two groups was marginal (p = 0.066), with a higher percentage in the overweight group (15.6%) compared to the obese group (6.6%) (Table 3).

Relative risk for fetal growth abnormalities in overweight and obese pregnant women

The relative risks (RR) for fetal growth abnormalities were calculated, both in general and for severe SGA, for LGA newborns and macrosomic newborns at term in overweight and obese pregnant women compared to those with a normal prepregnancy BMI (Table 4).

Overweight pregnant women were found to have a relative risk (RR) of 0.741 for fetal growth restriction (FGR), regardless of its type (95% CI [0.383-1.433]). The risk of severe SGA is 0.459 (95% CI [0.102-2.077]). The RR for LGA was increased by 1.75-fold (95% CI [1.166-2.631]), and for macrosomia at term, it was increased by 1.643-fold (95% [0.876-3.083]).

Among obese pregnant women, a moderately reduced relative risk (RR) for fetal growth restriction (FGR) was found overall, at 0.948 (95% CI [0.521-1.727]), but an increased risk for severe retardation was observed, 1.62 times (95% CI [0.672-4.202]). The risk of an LGA newborn was increased 1.51 times (95% CI [0.985-2.321]), and for fetal macrosomia at term, 1.24-fold (95% CI [0.605-2.562]).

DISCUSSION

The weight of a newborn at birth reflects how the fetus grows throughout its intrauterine life. A slow fetal growth rate results in a low newborn weight. Low birth weight may also be attributed to constitutional factors, a prerequisite that is absent in our overweight and obese pregnant study groups [7-9]. Only pregnant women with a normal BMI were included in the control group (CG), and no women with a BMI below the normal range were included. On the contrary, the high birthweight of the newborn is the result of an accelerated fetal growth rate in relation to constitutional causes (e.g., anthropometrically large mother, genetic predisposition) and environmental factors, which, in this case, are determined by the maternal organism. In overweight and obese women, fetal growth abnormalities may be bidirectional – both in the direction of their acceleration and in the direction of their retardation [10]. The pathogenesis of these processes is still under research. Maternal obesity and the abundance of adipose tissue affect the exchange of nutrients between the mother and the fetus. The biochemical milieu, in which the placenta develops in these cases, relates to the peculiarities of metabolism in obese women. The abundant adipose tissue produces a large amount of adiponectin, leptin, TNF-α, and interleukins [10, 11]. Through them, the placenta modulates “nutritional” signals to the fetus [12, 13]. The role of adiponectin in oxidative stress in the placenta and its association with the occurrence of FGR in cases without preeclampsia or gestational hypertension is assumed and increasingly discussed [11].

Delayed fetal growth

Many authors have reported an increased incidence of SGA among obese pregnant women, resulting in an increased rate of cesarean sections (CS) and the need for intensive neonatal care afterwards [14].

In our study, a total of 7.07% of obese pregnant women gave birth to fetuses with moderate or severe retardation, whereas the proportion among those who were overweight was 5.52%. In overweight pregnant women, moderate retardation predominates,

Table 4. Relative risk for fetal growth abnormalities in overweight and obese pregnant women

	Overweight (BMI≥25-29.9 kg/m^2)	**Obesity (BMI ≥30 kg/m^2)**
SGA<10th c	**0.741** (CI 95% [0.383-1.43])	**0.95 (**CI 95% [0.521-1.727])
Severe SGA (W <3rd centile)	**0.459** (CI 95% [0.102-2.047])	**1.62** (CI 95% [0.672-4.202])
LGA (W >90th centile)	**1.75** (CI 95% [1.166-2.631])	**1.51** (CI 95% [0.985-2.321])
Fetal macrosomia at term	**1.64** (CI 95% [0.876-3.0 = 83])	**1.24** (CI 95% [0.605-2.562])

Abbreviations: BMI – body mass index; CI – confidence interval; GA – gestational age; LGA – large for the gestational age; SGA – small for the gestational age; W – weight (of the newborn)

whereas in those with obesity, the ratio of moderate to severe retardation is 1:1. In our study, maternal overweight and obesity were not associated with an increased risk of SGA in general (relative risks of 0.741 and 0.95, respectively). However, within the obesity group, we observed a 1.62-fold increased risk for severe retardation. The findings of other authors are comparable. Tanner LD et al. (2022) investigated whether the incidence of severe retardation varies according to the severity of maternal obesity [15]. They conducted a retrospective, single-center cohort study involving 974 pregnant women with FGR. 70% (678) of the pregnant women had a normal BMI, defined by the authors as less than 29.9kg/m2. The criteria for obesity were defined according to the World Health Organization (WHO) classification of obesity. With class I obesity, were 15% of the pregnant women and class II and III also accounted for 15% of the cases. The authors found a significantly earlier gestational age (GA) at the time of diagnosis of FGR in obese pregnant women and a significant difference in the incidence of severe retardation among pregnant women with different BMI. Among those with a normal BMI, severe FGR was encountered in 29% of the cases, while among those with obesity, it was encountered in 37.8% of the cases. The higher the BMI of the pregnant woman, the earlier severe Doppler changes in feto-placental blood flow were diagnosed, specifically absent or reversed end-diastolic blood flow in the umbilical arteries. RR for severe FGR among obese pregnant women was calculated to be 1.4, similar to our research. The risk of abnormal Doppler findings in the umbilical arteries was increased 1.7-fold [15]. However, the cited results cannot be compared mechanistically with ours because the authors defined normal BMI differently, including overweight. In contrast, we have strictly adhered to the WHO criteria for BMI classification. Some authors have found that minimal (≤5 kg) or no weight gain during pregnancy in overweight and obese women is associated with an increased incidence of low birthweight for the gestational age [16]. A prospective study involving 1,053 pregnant women with high BMI who gained adequate weight during their pregnancy, compared to 188 who gained 5 kg or less or even lost weight, revealed that 4.9% of newborns in the first group, were retarded, whereas in the second group, were 9.6% (adjusted odds ratio (aOR) 2.6; 95% CI: 1.4-4.7, p = .003). Overall, the newborns of mothers who gained or lost little weight had lower mean birth weight (3258 ± 443 vs 3467 ± 492 g, p<.0001), less adipose tissue (403 ± 175 vs 471 ± 193 g, p<.0001), and lean mass (2855 ± 321 vs 2995 ± 347 g, p<.0001), smaller body length, and head circumference. However, regarding neonatal outcomes, no significant differences were found between the two groups of neonates.

The increased risk of FGR, both general and severe, in obese women may be linked to their higher prevalence of prepregnancy chronic hypertension and pregnancy-induced hypertensive disorders, including preeclampsia [17]. However, as already commented above, other plausible pathogenetic mechanisms explain the development of ischemic heart disease (IHD) in overweight and obese but nonhypertensive pregnant women [10-12].

Accelerated fetal growth

In our study, we discovered a 1.51-fold increased risk for LGA newborns in obese pregnant women and a 1.75-fold increased risk in those who were overweight. Maternal overweight and obesity rank among the most significant risk factors for fetal macrosomia, alongside gestational diabetes mellitus (GDM), age, parity, and a history of previous macrosomia [8, 9, 18]. These data suggest that it is likely that similar but markedly different pathogenetic mechanisms in overweight and obese women may be influencing fetal growth abnormalities. A BMI over 25 appears to be a significant predictor of macrosomia risk for the newborn, as noted by other authors [19, 20]. Increased nutrient supply to the fetus in obese pregnant women is associated with changes in fetal growth, resulting in large for gestational age (LGA) and macrosomic neonates [18, 21, 22]. There is also an increased risk of stillbirth [23, 24].

Lewandowska M et al. examined the associations between maternal obesity prior to pregnancy and newborn weight [20]. Low birthweight infants for g.w. were 6.6%, 2.3% with FGR and 10.6% with macrosomia. Adjusted risk for macrosomia was more than three times higher in obese mothers compared with those with normal BMI (aOR = 3.21 (1.69-6.1), p< 0.001). The risk profile for FGR was U-shaped: across the cohort, the risk was more than three times higher in obese (aOR = 3.12 (1.02-9.54), p 0.045) and underweight mothers (aOR = 3.84 (1.13-13.0), p = 0.031). The authors set the threshold values of maternal BMI for fetal macrosomia, for birth weight under 2500 g, and for FGR at 23.7 kg/m², 26.2 kg/m², and 31.8 kg/m², respectively. These results confirm the multidirectional effects of obesity on fetal growth, as it leads to low birth weight, fetal growth restriction, and macrosomia [20].

Kong L et al. investigated the relationship between overweight and obesity during pregnancy and newborn weight in uncomplicated pregnancies, as well as those complicated by GDM, among 649,043 births in Finland over a 10-year period (2004-2014) [19]. Of

these, 0.62% had insulin-dependent diabetes, 0.57% had type 2 diabetes, and 15.2% had GDM. According to the study, maternal moderate obesity without pregnancy complications was associated with an increased risk of LGA newborns (aOR 2.45; 95% CI: 2.29-2.62). The risk was considerably higher when overweight was coupled with insulin-dependent diabetes (aOR, 43.80; 95% CI: 40.88-46.93), with type 2 diabetes (12.44; 95% CI, 10.29-15.03), or with GDM (aOR, 4.72; 95% CI: 4.42-5.04) [19].

Ratnasiri A et al. conducted a retrospective cohort study involving 4,187,216 births from singleton pregnancies included in the California Birth Statistical Master Files (BSMF) database covering the period from 2007 to 2016 [25]. Pregnant women were categorised according to their prepregnancy BMI. Obesity was divided into classes I, II, and III. The authors examined various pregnancy outcome indicators, including low and very low birth weight, preterm birth, very early preterm birth, births of small-for-gestational-age and large-for-gestational-age newborns, and macrosomic newborns, as well as deliveries by cesarean section. Descriptive analysis, simple linear regression, and multivariable logistic regression were employed in this study, and adjusted odds ratios (aORs) with 95% confidence intervals were estimated for the associations with the complications above. During the study period, the prevalence of overweight and obesity increased by 4.3% and 22.9%, respectively [25]. Between 2007 and 2016, the prevalence of very low birth weight infants rose significantly as the BMI of pregnant women increased, by 24% in overweight women and by 76% in those with class III obesity. Women with Class III obesity had considerable increases in the rates of macrosomic and LGA newborns, specifically by 170% and 208%, respectively. Additionally, there were notable rises in preterm births by 33%, very early preterm births by 66% and births by CS by 208%. Obese women had no higher risk of giving birth to an SGA newborn, while those who were underweight had a 51% increased risk [25].

Deviations in fetal growth rate: short- and long-term outcomes for the offspring

The consequences of SGA are short-term and long-term. Immediately after birth, neonates with SGA, especially those with underlying FGR, face an increased risk of developing necrotizing enterocolitis, hypothermia and hypoglycemia due to reduced glycogen and fat stores and limited compensatory gluconeogenesis capacity [7, 26, 27]. Neonates with FGR are adapted to the intrauterine conditions of chronic hypoxia due to placental insufficiency. Therefore, compensatory processes of erythropoiesis are enhanced, resulting in high hematocrit values and blood hyperviscosity after birth. This can lead to acute neonatal adverse consequences such as necrotizing enterocolitis or thromboses, and respiratory complications [7]. The long-term outcomes include neurodevelopmental delay, cerebral palsy, and, according to Barker's hypothesis, susceptibility to conditions and diseases in adulthood, such as arterial hypertension, metabolic syndrome, and type 2 diabetes [28-31]. According to Howell KR et al., such children exhibit more frequent neuro-psychiatric and cognitive deviations [13]. Doppler studies on the cardiac function of fetuses of pregnant women with high BMI have shown that as early as 14 gestational weeks, there are changes in myocardial function, indicating that the predisposition to the future development of cardiovascular disease is established in early fetal life [32]. Accelerated fetal growth also affects postnatal life. The obesogenic prenatal environment predisposes to metabolic and cardiovascular diseases in adulthood. It is important to note that it is female newborns who are at greatest risk, especially if they themselves subsequently become obese [33]. Maternal obesity results in epigenetically altered gene expression associated with reproductive health in female offspring, alters ovarian follicle development in female fetuses, and reduces the number of primordial follicles, directly affecting future ovarian reserve [34]. High BMI is associated with increased estrogen levels and insulin resistance. In adulthood, daughters of obese mothers have impaired reproductive function, menstrual disorders and elevated androgen levels, and more commonly develop polycystic ovary syndrome (PCOS) and metabolic syndrome. The incidence of PCOS among them is significantly higher compared to daughters of mothers with normal BMI [35, 36].

Girls born with a high birth weight face a greater risk of becoming overweight or obese in the future, which, in turn, may lead to them giving birth to large children. This results in the so-called 'transgenerational effects' of obesity [28, 37-39].

CONCLUSIONS

Maternal prepregnancy BMI significantly influences fetal growth trajectories. Overweight and obese women have a higher incidence of large for gestational age newborns and macrosomia compared to women with a normal BMI. Obese women face an increased risk of severely low neonatal birthweight, with a high risk of FGR or SGA and on the opposite spectrum, fetal macrosomia. These conditions can lead to complications during delivery. They may have long-term health implications for the child, such as an increased

risk of obesity and metabolic disorders later in life. These findings emphasize the importance of managing maternal weight before and during pregnancy to mitigate adverse fetal outcomes and improve neonatal health, laying a foundation for healthier growth and development in early childhood.

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Authors' contributions: *M.Y. developed the study design and was the mentor of the research mentor, and refined the methodology of the study; I.H. and E.N. were responsible for data collection; E.N. conducted the statistical analysis; I.H. wrote the manuscript.*

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