Impact of prepregnancy body mass index on adverse pregnancy outcomes: analysis from the Longitudinal Indian Family hEalth cohort study

Monica Gudipally, MD; Fouzia Farooq, PhD, MPH; Kalpana Basany, MD; Catherine L. Haggerty, PhD, MPH; Gong Tang, PhD; Govindrao N. Kusneniwar, MD; Guru Rajesh Jammy, PhD, MPH; Clareann H. Bunker, PhD; P.S. Reddy, MD

BACKGROUND: Both high and low maternal prepregnancy body mass index can lead to suboptimal fetal growth and risk of pregnancy complications. In developed countries, nearly half of all women of childbearing age are either overweight or obese, and most data linking maternal body mass index and adverse pregnancy complications are limited to these populations.

OBJECTIVE: This study aimed to prospectively evaluate the relationships between prepregnancy body mass index and adverse pregnancy outcomes using the Longitudinal Indian Family hEalth (LIFE) study.

STUDY DESIGN: We modeled the relationships between prepregnancy body mass index and adverse pregnancy outcomes such as low birthweight, preterm birth, cesarean delivery, intrauterine growth restriction, miscarriage, and fetal death among 675 women aged 15 to 35 years with singleton pregnancies in the Longitudinal Indian Family hEalth study, a population-based prospective pregnancy cohort study conducted in Telangana, India. Prepregnancy body mass index was calculated as weight in kilograms divided by height in meters squared and was classified into 4 categories using the World Health Organization recommendations for Asian adults. Prepregnancy body mass index was assessed at a mean of 12.3 months before pregnancy. Odds ratios and 95% confidence intervals of adverse pregnancy outcomes were modeled and adjusted for confounders.

RESULTS: Obese women had a 3-fold increased risk of cesarean delivery (odds ratio, 3.13; 95% confidence interval, 1.56−6.29) compared with normal-weight women. Those who were overweight also had a marginally increased risk of cesarean delivery, albeit not statistically significant (odds ratio, 1.17; 95% confidence interval, 0.61−2.24). Underweight women had a modestly increased risk of low birthweight, compared with normal-weight women (odds ratio, 1.12; 95% confidence interval, 0.71−1.77), although results were not significant. Conversely, obese (odds ratio, 0.71; 95% confidence interval, 0.28−1.77) and overweight (odds ratio, 0.61; 95% confidence interval, 0.24−1.51) women had a marginally decreased risk of low birthweight.

CONCLUSION: Our data suggest that women with elevated prepregnancy body mass index may have a higher risk of adverse pregnancy outcomes, especially cesarean delivery. Although this study has limited generalizability, our findings are generalizable to rural to periurban regions of India. Further studies exploring the translatability of these findings to other populations are needed. In addition, targeted prepregnancy intervention studies and programs that include counseling on optimization of preconception health and lifestyle modification for improvement of subsequent pregnancy outcomes among overweight and obese women are needed.

Keywords: cesarean delivery, fetal death, intrauterine growth restriction, low birthweight, miscarriage, preconception, preterm birth, stillbirth, weight

From the Society for Health Allied Research and Education (SHARE) INDIA MediCiti Institute of Medical Sciences, Ghanpur, India; World Health Organization, Hyderabad, India; Department of Community Medicine and Family Medicine, All India Institute of Medical Sciences, Bibinagar, Bibinagar, India; Department of Epidemiology, University of Pittsburgh, Pittsburgh, PA; Department of Biostatistics, University of Pittsburgh, Pittsburgh, PA; Division of Cardiology, Department of Medicine, University of Pittsburgh School of Medicine, University of Pittsburgh, Pittsburgh, PA; Department of Community Medicine, ESIC Medical College and Hospital, Sanathnagar, Hyderabad, India

The authors report no conflict of interest.

This project was supported by the Society for Health Allied Research and Education (SHARE) INDIA Research Foundation and their fundraising efforts, and by the John E. Fogarty International Center of the National Institutes of Health training program (award number D43 TW 009078). The funding source had no involvement in the conduct of the research or the preparation, submission, or publication of this manuscript. This research was conducted before G.R.J. joined the World Bank. The findings and views do not reflect those of the World Bank.

Patient consent was not required because no personal information or details were included.

Cite this article as: Gudipally M, Basany K, Farooq F, et al. Impact of prepregnancy body mass index on adverse pregnancy outcomes: analysis from the Longitudinal Indian Family hEalth cohort study. Am J Obstet Gynecol Glob Rep 2022;XX:x.ex−x.ex.

Corresponding author: Kalpana Basany, MD; kalpanabasany@gmail.com

2666-5778/$36.00

http://dx.doi.org/10.1016/j.xagr.2022.100134

AJOG MFM at a Glance

Why was this study conducted?
This study was conducted to assess the impact of prepregnancy body mass index (BMI) on risk of adverse pregnancy outcomes in women of reproductive age in India.

Key findings
Women who are obese before pregnancy have an increased risk of cesarean delivery, compared with normal-weight women.

What does this add to what is known?
Although our findings add to the literature demonstrating that high prepregnancy BMI is associated with cesarean delivery, most previously published work has been conducted in developed countries, whereas our study was conducted in India. In addition, our pregnancy cohort study recruited women before conception; this allowed us to capture BMI and other relevant variables in the preconception window and study their impact on pregnancy outcomes.

Introduction
Maternal prepregnancy body mass index (BMI) and sufficient gestational weight gain are measures of maternal health and nutrition that are key to meeting the nutrient demands of pregnancy. These factors are also vital for healthy embryonic and fetal development and infant health. Although sufficient dietary intake is critically important for fetal development, excessive maternal weight is associated with pregnancy complications and increases the risk of childhood obesity and adverse cardiovascular outcomes.[1] Optimization of prepregnancy BMI is thus critically important for normal fetal growth and development.[2]

Both low and high maternal BMI are linked to adverse pregnancy outcomes.[3−8] Mothers with low prepregnancy BMI are more likely to have suboptimal fetal growth, leading to low birthweight (LBW),[9−13] preterm delivery,[9,14−16] intrauterine growth restriction (IUGR),[9,13] smaller head circumference, and low ponderal index, all of which are associated with higher infant morbidity and mortality.[13,17−19] High maternal prepregnancy BMI increases the risk of complications including preeclampsia,[14,15,20−27] gestational diabetes mellitus,[14,15,20,21,23−28] cesarean delivery,[11,14,15,20,21,23,25,27,29−33] preterm delivery,[34−36] stillbirth,[24,32,37] large-for-gestational-age or fetal macrosomia,[20,21,23,25,27,31,38−41] postpartum infection or blood clots,[14] postpartum weight retention,[11,42] and late initiation of breast feeding, leading to early introduction of solid foods to the infant.[20,43,44]

In developed countries, nearly half of all women of childbearing age are either overweight or obese,[3] and most data linking maternal BMI and adverse pregnancy outcomes are limited to these populations. Data linking prepregnancy BMI and adverse pregnancy outcomes in developing countries, including India, are sparse. A recent study conducted in Chennai, India observed that higher-than-recommended gestational weight gain among women categorized as overweight or obese before pregnancy had an increased risk of adverse pregnancy outcomes.[45] According to the 2015−2016 Indian National Family Health Survey (NFHS)-4, approximately 23% and 21% of reproductive-age women (15−45 years) have BMI <18.5 kg/m^2 and >25.5 kg/m^2, respectively.[46] Within Telangana state, these estimates are approximately 23% and 28%, respectively.[46] Because both low and high prepregnancy BMI are relatively frequent in India, our objective was to analyze prepregnancy BMI as a predictor of adverse pregnancy outcomes in the prospective Longitudinal Indian Family hEalth (LIFE) pregnancy cohort study in a periurban area of Medchal Mandal in Telangana state. Specifically, we explored the links between preconception BMI categories of underweight, normal, overweight, and obese, and a range of adverse pregnancy outcomes.

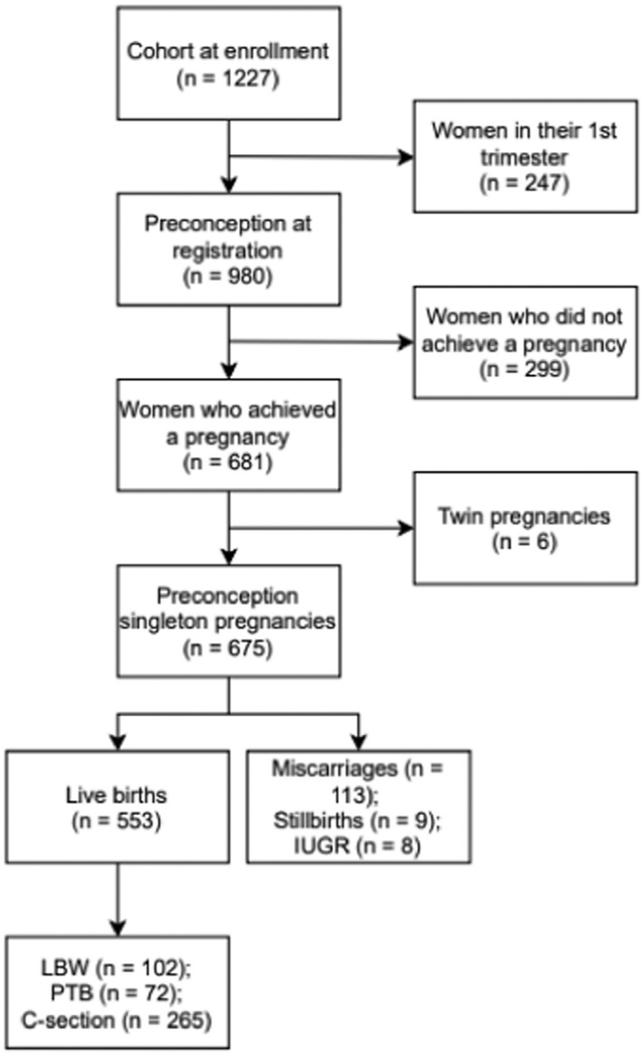
Materials and Methods
Study design and population
We conducted a prospective analysis using data from the LIFE study. The design and procedures of the LIFE study have been described previously.[47] Briefly, LIFE is a prospective pregnancy cohort study established in 2009 in a periurban area of Medchal Mandal of Telangana state, India, approximately 40 km from the city of Hyderabad. The cohort was established with the aim of examining how environmental, infectious, lifestyle, metabolic, and genetic factors before conception and during pregnancy affect birth outcomes and early childhood health and development. A total of 1227 married women were recruited before conception (n=980) or within the first trimester of pregnancy (n=247) during the 2-year recruitment period (2009−2011) and were followed up through pregnancy, delivery, and postpartum for birth outcomes. Information on demographic characteristics was obtained at the baseline visit through self-report with standardized questionnaires. To test our hypothesis, this analysis was restricted to women in this cohort who were recruited during the preconception period (n=980), who conceived (n=681), and who experienced a live birth (n=553), a miscarriage (n=113), and/or stillbirth (n=9). Because women with multiple gestations have an increased risk of adverse pregnancy outcomes,[48,49] we excluded twin pregnancies (n=6), leaving a remaining n=675 for analysis (Figure 1).

This study was approved by both University of Pittsburgh's and the Society for Health Allied Research and Education (SHARE) INDIA's institutional review boards and their ethics committees (SHARE INDIA, approved November 9, 2009; University of Pittsburgh [PRO08070108], approved September 15, 2009). Informed consent was obtained from all participants before study onset.

Exposure classification
BMI categories were created from height and weight measurements that were taken at the baseline visit using a portable seca scale (model 813 robust

FIGURE 1

Longitudinal Indian Family hEalth study pregnancy cohort*IUGR*, intrauterine growth restriction; *LBW*, low birthweight; *PTB*, preterm birth.



Gudipally. Prepregnancy body mass index is associated with increased risk of cesarean delivery. Am J Obstet Gynecol Glob Rep 2022.

adult; seca GmbH & Co. KG., Hamburg, Germany) designed by the United Nations Children's Fund (UNICEF). All measurements were taken using the standard protocol described in Lohman et al.[50] Prepregnancy maternal BMI was calculated as weight in kilograms divided by height in meters squared, and classified into 4 categories per World Health Organization (WHO) recommendations for Asian adults.[51]

Pregnancy outcomes

On the basis of standard definitions used by the US Centers for Disease Control and Prevention and the WHO, LBW was defined as a birthweight of <2500 g.[52,53] Preterm birth (PTB) was defined as a live birth that occurred before 37 completed weeks of gestation. IUGR was defined by birthweight <10th percentile of the average for gestational age, defined clinically and using fetal Doppler. Births were classified as either vaginal or cesarean deliveries. Miscarriage was defined as the loss of a fetus before 20 weeks of gestation.[54] Fetal death was defined as a spontaneous intrauterine death of a fetus at any time during the pregnancy. This broader definition included both miscarriages and stillbirth (pregnancy loss occurring at ≥20 weeks of gestation).

To ascertain a pregnancy, women were interviewed monthly to obtain the date of their last menstrual period. Staff members followed up with a phone call after the expected menstrual date. If a menstrual date was missed, staff members arranged a time to visit and perform a urine test. Staff members called and scheduled visits regularly throughout the pregnancy (first and third trimesters). Data from the labor and delivery medical records from each hospital where the participants delivered were abstracted by study staff using a standardized study data collection form. All study data were entered into a database by a member of the data staff team. A double-key entry system was used to ensure accuracy of data entry.

Mediation by hypertensive disorders of pregnancy

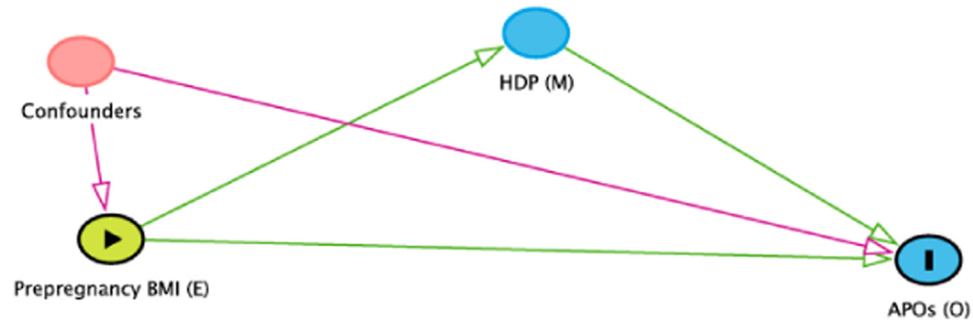
To disentangle the pathways that link prepregnancy BMI to the outcomes of interest, we also conducted exploratory analyses examining the total effect of prepregnancy BMI, the indirect effect of prepregnancy BMI operating through the mediator, hypertensive disorders of pregnancy (HDP) (including preeclampsia, eclampsia, pregnancy-induced hypertension, or gestational hypertension), and the direct effect of prepregnancy BMI that is not explained by HDP. For this exploratory analysis, we consolidated the overweight and obese categories because of the relatively small proportion of participants experiencing HDP (n=49) when further split by each BMI category (normal weight [n=19], underweight [n=14], overweight [n=10], obese [n=6]). A directed acyclic graph shows the direct and indirect pathway to the outcomes of interest (adverse pregnancy outcomes) (Figure 2).

Statistical analysis

Descriptive analyses were performed for BMI category and baseline characteristics. Maternal characteristics were compared between the BMI categories using the Pearson chi-square test of proportions for categorical variables and

FIGURE 2

Relationship between prepregnancy BMI, HDP, and APOs<FIGTIT>Directed acyclic graph demonstrating the direct and indirect relationship between prepregnancy BMI, HDP, and APOs.



APO, adverse pregnancy outcome; *BMI*, body mass index; *E*, Exposure; *HDP*, hypertensive disorders of pregnancy; *M*, Mediator; *O*, Outcome.<FIGSE>

Gudipally. Prepregnancy body mass index is associated with increased risk of cesarean delivery. Am J Obstet Gynecol Glob Rep 2022.

analysis of variance for continuous variables. Independent variables with *P* values <.20 were selected for inclusion in the models, in addition to a priori selected confounders for each outcome. Potential confounders included women's age at conception,[4] time between preconception measures and pregnancy,[55] education,[6] and previous cesarean delivery.[56] Multivariable logistic regression models were used to characterize the odds ratios (ORs) of adverse pregnancy outcomes across BMI categories. HDP were also assessed as a potential mediator in this analysis using the medflex package 0.6-7[57] and car package 3.0-10.[58] R version 4.0 (R Core Team, Vienna, Austria) was used for statistical analysis. For each outcome, except IUGR (because of lack of events in the overweight and obese BMI categories), interactions between prepregnancy BMI and parity and between prepregnancy BMI and maternal age at conception were assessed.

Results

Of the 675 women recruited before conception, 44.7% were categorized as normal-weight, 38.1% were underweight, 8.1% were overweight, and 9.1% were obese. Table 1 summarizes baseline maternal characteristics and pregnancy outcomes stratified by BMI category. Generally, there was a trend toward increasing age with greater BMI (*P*<.001). Most women were homemakers, belonged to Hindu religion, and reported an education level of middle school or below. Second-hand smoke exposure was reported by 17% and alcohol consumption by 19% of participants. No women reported first-hand smoking, and tobacco chewing was rare (n=3; 0.4%), thus neither are included in the table. Cardiometabolic laboratory measurements including total cholesterol, triglycerides, high- and low-density lipoprotein cholesterol, and very-low-density lipoprotein were observed to differ significantly by BMI category. Previous pregnancy complications, HDP, and cesarean delivery in previous pregnancy were significantly different among the BMI categories, although the number of women in each category was small. The prevalence of HDP was greater in obese and overweight women than in women who were either underweight or of normal weight.

Rates of LBW, PTB, cesarean delivery, IUGR, miscarriage, and fetal death were 18.4%, 13.0%, 47.9%, 1.2%, 16.7%, and 18.1%, respectively, among the 675 women included in the analysis. The cesarean delivery rates differed significantly (*P*<.001), with the highest being among obese women (75.5%) compared with other categories (normal weight, 49.6%; underweight, 38.6%; and overweight, 53.5%).

Table 2 summarizes the association between maternal prepregnancy BMI categories and adverse pregnancy outcomes. Compared with normal-weight women, those who were obese had a statistically significant 3-fold increased risk of cesarean delivery (OR, 3.13; 95% confidence interval [CI], 1.56−6.29). Those who were underweight had a statistically significant 36% decreased risk of cesarean delivery (OR, 0.64; 95% CI, 0.44−0.93). Overweight women were also at a marginally increased risk of cesarean delivery, although this relationship was not statistically significant (OR, 1.17; 95% CI, 0.61−2.24). After adjusting for maternal age at conception, time between preconception measure and pregnancy, and previous cesarean delivery, the nonsignificant trends remained for both underweight (adjusted OR [aOR], 0.69; 95% CI, 0.44 −1.07) and overweight categories (aOR, 0.86; 95% CI, 0.38−1.91).

Women who were underweight had a modestly increased risk of LBW (OR, 1.12; 95% CI, 0.71−1.77) compared with normal-weight women. Women who were in the overweight (OR, 0.71; 95% CI, 0.28−1.77) and obese (OR, 0.61; 95% CI, 0.24−1.51) categories had a marginally decreased risk of LBW. Compared with normal-weight women, women who were underweight (OR, 1.21; 95% CI, 0.71−2.08) and those who were obese (OR, 1.20; 95% CI, 0.49 −2.91) had a 1.2-fold increased risk of PTB. Women in the overweight category were 25% less likely to experience a PTB (OR, 0.74; 95% CI, 0.25−2.21). Results were similar after adjustment for confounders.

TABLE 1

Demographic and clinical characteristics of women in the Longitudinal Indian Family hEalth study according to body mass index category (n=675)

		Maternal BMI				
Characteristics	Overall (n=675)	Normal 18.5−22.9 kg/m² n (%) (n=302)	Underweight <18.5 kg/m² n (%) (n=257)	Overweight 23−24.9 kg/m² n (%) (n=55)	Obese ≥25 kg/m² n (%) (n=61)	*P* value
Demographics						
Age at conception (y), mean (SD)	22.9 (3.2)	23.0 (3.1)	22.3 (2.7)	23.8 (3.4)	24.8 (4.6)	<.001
Time between preconception measures and pregnancy (mo), mean (SD)	12.3 (14.3)	12.2 (13.3)	11.7 (14.1)	11.4 (13.1)	16.5 (19.7)	.111
Homemaker (% yes)	516 (76.4)	233 (77.2)	191 (74.3)	47 (85.5)	45 (73.8)	.327
Religion						.005
Hindu	609 (90.2)	275 (91.1)	234 (91.1)	47 (85.5)	53 (86.9)	
Muslim	40 (5.9)	19 (6.3)	7 (2.7)	7 (12.7)	7 (11.5)	
Christian	26 (3.9)	8 (2.6)	16 (6.2)	1 (1.8)	1 (1.6)	
Caste						.047
Scheduled Caste	141 (20.9)	57 (18.9)	63 (24.5)	10 (18.2)	11 (18.0)	
Scheduled Tribe	49 (7.3)	20 (6.6)	25 (9.7)	2 (3.6)	2 (3.3)	
Backward caste	387 (57.3)	181 (59.9)	142 (55.3)	31 (56.4)	33 (54.1)	
Other	98 (14.5)	44 (14.6)	27 (10.5)	12 (21.8)	15 (24.6)	
Education						.528
Middle school	276 (40.9)	126 (41.7)	109 (42.4)	19 (34.5)	22 (36.1)	
High school	255 (37.8)	110 (36.4)	102 (39.7)	21 (38.2)	22 (36.1)	
College	144 (21.3)	66 (21.9)	46 (17.9)	15 (27.3)	17 (27.9)	
Parity						.723
0	273 (40.4)	126 (41.7)	99 (38.5)	20 (36.4)	28 (45.9)	
1	306 (45.3)	130 (43.0)	126 (49.0)	26 (47.3)	24 (39.3)	
≥2	96 (14.2)	46 (15.2)	32 (12.5)	9 (16.4)	9 (14.8)	
Consanguinity (% yes)	157 (23.3)	69 (22.8)	67 (26.1)	10 (18.2)	11 (18.0)	.408
Second-hand smoking (% yes)	117 (17.3)	44 (14.6)	57 (22.2)	8 (14.5)	8 (13.1)	.076
Cardiometabolic laboratory measurements						
Preconception dyslipidemia (% yes)	454 (67.3)	209 (69.2)	146 (56.8)	45 (81.8)	54 (88.5)	<.001
Total cholesterol mg/dL, mean SD)	146.0 (31.1)	146.0 (31.5)	138.7 (26.3)	162.7 (35.7)	161.6 (32.0)	<.001
Triglycerides mg/dL, mean (SD)	67.0 (38.3)	68.0 (36.2)	55.8 (26.0)	76.2 (47.7)	100.5 (56.7)	<.001
HDL-c mg/dL, mean (SD)	46.3 (10.5)	46.5 (10.6)	48.0 (10.4)	43.0 (10.0)	41.4 (8.7)	<.001
LDL-c mg/dL, mean (SD)	86.5 (26.8)	86.2 (27.1)	79.7 (22.4)	104.5 (30.8)	100.2 (26.5)	<.001
VLDL mg/dL, mean (SD)	13.4 (7.6)	13.6 (7.3)	11.2 (5.2)	15.2 (9.5)	19.9 (11.3)	<.001
Preconception hypertension (% yes)	38 (5.6)	21 (7.0)	9 (3.5)	3 (5.5)	5 (8.2)	.267
SBP (mm Hg), mean (SD)	112.8 (10.6)	113.0 (11.0)	112.3 (10.8)	113.1 (9.7)	113.6 (9.1)	.805
DPB (mm Hg), mean (SD)	73.7 (8.6)	74.0 (8.9)	72.5 (8.1)	74.9 (8.7)	76.1 (7.9)	.012
Preconception diabetes mellitus (% yes)	5 (0.7)	1 (0.3)	2 (0.8)	0 (0.0)	2 (3.3)	.092
Fasting blood glucose mg/dL	88.8 (19.2)	89.5 (25.9)	86.3 (9.7)	91.0 (9.7)	93.9 (15.0)	.019
Preconception hypothyroidism/goiter (% yes)	17 (2.5)	7 (2.3)	7 (2.7)	0 (0.0)	3 (4.9)	.400
fT3, mean (SD) pg/dL	3.2 (0.5)	3.2 (0.5)	3.2 (0.5)	3.2 (0.5)	3.1 (0.5)	.719
fT4, mean (SD) ng/dL	1.3 (0.3)	1.3 (0.4)	1.3 (0.3)	1.3 (0.3)	1.4 (0.4)	.626
TSH, mean (SD) μIU/mL	6.0 (25.2)	4.9 (15.9)	8.0 (36.1)	4.2 (13.3)	4.5 (11.6)	.458
Preconception anemia (% yes)	345 (51.1)	151 (50.0)	138 (53.7)	28 (50.9)	28 (45.9)	.682
Obstetrical history						
Previous obstetrical complications						.021
Primigravida	250 (37.0)	117 (38.7)	91 (35.4)	17 (30.9)	25 (41.0)	

Gudipally. Prepregnancy body mass index is associated with increased risk of cesarean delivery. Am J Obstet Gynecol Glob Rep 2022.

(continued)

TABLE 1
Demographic and clinical characteristics of women in the Longitudinal Indian Family hEalth study according to body mass index category (n=675) *(continued)*

Characteristics	Overall (n=675)	Maternal BMI: Normal 18.5–22.9 kg/m² n (%) (n=302)	Underweight <18.5 kg/m² n (%) (n=257)	Overweight 23–24.9 kg/m² n (%) (n=55)	Obese ≥25 kg/m² n (%) (n=61)	*P* value
Multigravida with complications	208 (30.8)	94 (31.1)	68 (26.5)	27 (49.1)	19 (31.1)	
Multigravida without complications	217 (32.1)	91 (30.1)	98 (38.1)	11 (20.0)	17 (27.9)	
Hypertensive disorders during pregnancy and labor (% yes)	49 (7.3)	19 (6.3)	14 (5.4)	10 (18.2)	6 (9.8)	.007
Gestational diabetes mellitus (% yes)	7 (1.0)	4 (1.3)	0 (0.0)	3 (5.5)	0 (0.0)	.003
Cesarean delivery in previous pregnancy						.003
Nulliparous	297 (44.0)	134 (44.4)	126 (49.0)	22 (40.0)	15 (24.6)	
Previous cesarean delivery (% no)	268 (39.7)	122 (40.4)	99 (38.5)	20 (36.4)	27 (44.3)	
Previous cesarean delivery (% yes)	110 (16.3)	46 (15.2)	32 (12.5)	13 (23.6)	19 (31.1)	
Outcomes						
LBW (% yes)	102 (18.4)	46 (18.7)	44 (20.5)	6 (14.0)	6 (12.2)	.489
PTB (% yes)	72 (13.0)	30 (12.2)	31 (14.4)	4 (9.3)	7 (14.3)	.774
Cesarean delivery (% yes)	265 (47.9)	122 (49.6)	83 (38.6)	23 (53.5)	37 (75.5)	<.001
IUGR (% yes)	8 (1.2%)	4 (50)	4 (50)	—	—	—
Miscarriage (% yes)	113 (16.7)	53 (17.5)	39 (15.2)	9 (16.4)	12 (19.7)	.807
Fetal death (% yes)	122 (18.1)	56 (18.5)	42 (16.3)	12 (21.8)	12 (19.7)	.755

BMI, body mass index; *DBP*, diastolic blood pressure; *fT3*, free triiodothyronine; *fT4*, free tetraiodothyronine; *HDL-c*, high-density cholesterol; *IUGR*, intrauterine growth restriction; *LBW*, low birthweight; *LDL-c*, low-density cholesterol; *PTB*, preterm birth; *SBP*, systolic blood pressure; *SD*, standard deviation; *TSH*, tyroid stimulating hormone; *VLDL*, very low-density cholesterol.

Gudipally. Prepregnancy body mass index is associated with increased risk of cesarean delivery. Am J Obstet Gynecol Glob Rep 2022.

Women who were underweight had an 18% increased risk of IUGR, compared with normal-weight women, although results were not statistically significant (OR, 1.18; 95% CI, 0.29–4.76; aOR, 1.21; 95% CI, 0.3–4.97). Women who were obese compared with women with normal weight had a 15% nonsignificant increased risk of miscarriage (OR, 1.15; 95% CI, 0.57–2.31). After adjusting for maternal age at conception, time between preconception measures and pregnancy, education level, second-hand smoking, and parity, the risk disappeared (aOR, 0.95; 95% CI, 0.46–1.98). Lastly, women who were overweight had a nonsignificantly increased risk of fetal death (OR, 1.23; 95% CI, 0.61–2.48) compared with normal-weight women. The risk was attenuated after adjusting for maternal age at conception, time between preconception measures and pregnancy, education level, and second-hand smoking (aOR, 1.10; 95% CI, 0.54–2.26).

Exploratory analyses considering HDP as a mediator and normal weight as the reference category for prepregnancy BMI did not show a difference between the BMI exposure levels and any of the outcomes in the natural direct and indirect effects (Appendix A, Table A.1). Interactions between prepregnancy BMI and parity were insignificant for all outcomes (LBW $P>.05$; PTB $P>.05$; cesarean delivery $P>.05$; miscarriage $P>.05$; fetal death $P>.05$) and between prepregnancy BMI and maternal age at conception for all outcomes (LBW, $P>.05$; PTB, $P>.05$; cesarean delivery, $P>.05$; miscarriage, $P>.05$; fetal death, $P>.05$).

Comment

Principal findings

In our pregnancy cohort study of women recruited before conception in a rural to periurban region of India, we demonstrated that women who have an increased BMI before pregnancy have a significantly higher risk of cesarean delivery than women who have a normal BMI. The impact of BMI was strong, demonstrated by a 3-fold elevated risk of cesarean delivery among obese women compared with women of normal BMI. In addition, we found marginally increased risks of LBW in women who were underweight, of PTB in women who were underweight and obese, and of fetal death among women who were overweight, relative to women with normal BMI.

Results in the context of what is known

These findings are intuitive because elevated prepregnancy BMI is associated with pregnancy complications that can lead to adverse maternal and fetal outcomes, including obstetrical interventions at birth.[59–61] Our findings are in line with several studies demonstrating that women with higher BMI are more likely to deliver by cesarean delivery than by vaginal birth, but most previously published work has been conducted in developed countries using retrospective cohorts or BMI from early in the first trimester.[62–73] The overall rates of adverse pregnancy outcomes in our study are also in line with the current rates in India. A recent publication by Khan et al[74] reported a LBW rate of 16.4% (95% CI, 16.1–16.8), and a PTB rate of 5% to 18% was reported by the National Health Portal of India.[75] The rates of cesarean delivery, which is not uncommon in populations undergoing transition, have been rising in countries such as India. The NFHS-5 showed that the rate of cesarean delivery was 42.4% in Andhra Pradesh, 31.3% in Lakshadweep, and 41.7% in Jammu and Kashmir.[76] Our study was designed as a

TABLE 2
Prepregnancy body mass index and risk of adverse pregnancy outcomes

Pregnancy Outcomes		OR, 95% CI, *P* value	aOR, 95% CI, *P* value
LBW[a] (n=553)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	1.12, 95% CI (0.71−1.77), .633	0.50, 95% CI (0.08−2.98), .446
	Overweight	0.71, 95% CI (0.28−1.77), .457	1.08, 95% CI (0.68−1.72), .741
	Obese	0.61, 95% CI (0.24−1.51), .283	0.71, 95% CI (0.28−1.77), .459
PTB[b] (n=553)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	1.21, 95% CI (0.71−2.08), .483	1.19, 95% CI (0.69−2.06), .539
	Overweight	0.74, 95% CI (0.25−2.21), .588	0.72, 95% CI (0.24−2.17), .558
	Obese	1.20, 95% CI (0.49−2.91), .687	1.28, 95% CI (0.52−3.15), .589
Cesarean delivery[c] (n=553)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	0.64, 95% CI (0.44−0.93), .018	0.69, 95% CI (0.44−1.07), .098
	Overweight	1.17, 95% CI (0.61−2.24), .638	0.86, 95% CI (0.38−1.91), .704
	Obese	3.13, 95% CI (1.56−6.29), .001	1.85, 95% CI (0.82−4.17), .139
IUGR[a] (n=675)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	1.18, 95% CI (0.29−4.76), .818	1.21, 95% CI (0.3−4.97), .788
	Overweight	—	—
	Obese	—	—
Miscarriage[d] (n=675)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	0.84, 95% CI (0.54−1.32), .451	0.94, 95% CI (0.59−1.5), .797
	Overweight	0.92, 95% CI (0.42−1.99), .831	0.83, 95% CI (0.38−1.84), .647
	Obese	1.15, 95% CI (0.57−2.31), .693	0.95, 95% CI (0.46−1.98), .898
Fetal death[e] (n=675)	BMI categories		
	Normal	Ref.	Ref.
	Underweight	0.86, 95% CI (0.55−1.33), .496	0.93, 95% CI (0.59−1.45), .738
	Overweight	1.23, 95% CI (0.61−2.48), .570	1.10, 95% CI (0.54−2.26), .790
	Obese	1.08, 95% CI (0.54−2.16), .837	0.97, 95% CI (0.48−1.99), .941

aOR, adjusted odds ratio; *BMI*, body mass index; *CI*, confidence interval; *IUGR*, intrauterine growth restriction; *LBW*, low birthweight; *OR*, odds ratio; *PTB*, preterm birth; *Ref*, reference interval.

[a] Adjusted for mother's age at conception and time between preconception measures and pregnancy; [b] Adjusted for mother's age at conception, time between preconception measures and pregnancy, and education; [c] Adjusted for mother's age at conception, time between preconception measures and pregnancy, and previous cesarean delivery; [d] Adjusted for mother's age at conception, time between preconception measures and pregnancy, education level, second-hand smoking, and parity; [e] Adjusted for mother's age at conception, time between preconception measures and pregnancy, education level, and second-hand smoking.

Gudipally. Prepregnancy body mass index is associated with increased risk of cesarean delivery. Am J Obstet Gynecol Glob Rep 2022.

pregnancy cohort study recruiting before conception, which allowed us to capture BMI and other relevant variables in the preconception window and study their impact on pregnancy outcomes.

Clinical implications

Obesity has been prevalent among reproductive-age women in both high-income and low-middle−income countries.[77] Obese women are also at an increased risk of gestational diabetes mellitus, which can subsequently lead to type 2 diabetes mellitus. In addition, obesity affects fetal growth negatively, leading to large-for-gestational age fetuses and birth defects such as heart and neural tube defects.[77,78] Our findings suggest that including prepregnancy BMI counseling and intervention during preconception health encounters may be important in mitigating adverse pregnancy outcomes such as cesarean delivery in subsequent pregnancies, specifically in populations with high rates of obesity. Indian populations are shown to have acquired dietary patterns of urbanization that are high in fats, sugars, and salt, leading to increasing obesity rates in reproductive-age women.[79] In India and other countries with elevated or rising rates of obesity in women, tackling malnutrition, encouraging physical activity, and health promotion in clinical settings could help encourage women to make healthy lifestyle choices that would lead to improved BMI and pregnancy outcomes.

Research implications

Studies in various populations have shown an association between low[80−82] and high[66,81,83] prepregnancy BMI and birthweight and between low[84−86] and high[35,65,81] prepregnancy BMI and risk of PTB, although other studies have shown inconclusive results,[13,87] and comparison across studies and populations is often difficult because of variation in BMI categorization.[13,54,80,81,83,88−101] Hence, future intervention trials and research studies are warranted to optimize preconception BMI to assess the impact on pregnancy outcomes.

Strengths and limitations

Our study has several notable strengths. We measured BMI prior to pregnancy and followed women throughout pregnancy. Most previous studies used "prepregnancy" BMI calculated at the first antenatal visit rather than before conception.[14,28,103–105] In addition, large prospective preconception studies are sparse globally and do not follow-up women throughout pregnancy and beyond. Our study design allowed for the collection of detailed reproductive history, lifestyle, environment, and medical history at preconception. Given the large sample size at preconception, our study was uniquely equipped to conduct a robust primary analysis of the association between prepregnancy BMI and adverse birth outcomes.

There are a few weaknesses to consider when interpreting our data. Because the sample was taken exclusively from the Medchal region of Telangana state, this could limit the generalizability of the findings to the larger Indian population. In addition, a large percentage of previous cesarean delivery data were missing in our dataset because not all women delivered or previously sought care at the study hospital (MediCiti Institute of Medical Sciences). If a woman had been pregnant in the past but her delivery status was missing, an assumption was made that she did not have a cesarean delivery in a previous pregnancy. This was considered a reasonable approach because women who are at high risk of cesarean delivery are referred to MediCiti. Lastly, results for the outcome of IUGR were largely inconclusive because of its rare occurrence in our study.

Conclusion

Our finding that increased prepregnancy BMI is associated with a significantly higher risk of cesarean delivery in a subsequent pregnancy combined with the increasing prevalence of obesity in India suggests an urgent need for development and testing of interventions to optimize prepregnancy health, including BMI. General lack of preventive care and accessibility to health care in India is a major barrier to providing women in their reproductive prime with the care needed to enter a pregnancy in optimal health. An upward trend in obesity among reproductive-age individuals in India[105] should be taken as a call to action and underscores the need to design intervention programs focused on obesity screening, prevention, treatment, and management. Given that we demonstrated a link between obesity and adverse pregnancy outcomes, we can expect this impact to amplify if obesity continues to rise. Epidemiologic studies exploring the rates of both obesity and adverse pregnancy outcomes over time could also provide insight. Ultimately, clinical trials exploring the impact of obesity intervention programs on pregnancy outcomes are needed. ■

REFERENCES

1. Kelly AC, Powell TL, Jansson T. Placental function in maternal obesity. Clin Sci (Lond) 2020;134:961–84.
2. Hanson MA, Bardsley A, De-Regil LM, et al. The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: "Think Nutrition First. Int J Gynaecol Obstet 2015;131:S213–53.
3. Liu P, Xu L, Wang Y, et al. Association between perinatal outcomes and maternal prepregnancy body mass index. Obes Rev 2016;17:1091–102.
4. Sun Y, Shen Z, Zhan Y, et al. Effects of prepregnancy body mass index and gestational weight gain on maternal and infant complications. BMC Pregnancy Childbirth 2020;20:390.
5. Li L, Chen Y, Lin Z, et al. Association of prepregnancy body mass index with adverse pregnancy outcome among first-time mothers. PeerJ 2020;8:e10123.
6. Ding XX, Xu SJ, Hao JH, Huang K, Su PY, Tao FB. Maternal pre-pregnancy BMI and adverse pregnancy outcomes among Chinese women: results from the C-ABCS. *Journal*. J Obstet Gynaecol 2016;36:328–32.
7. Athukorala C, Rumbold AR, Willson KJ, Crowther CA. The risk of adverse pregnancy outcomes in women who are overweight or obese. BMC Pregnancy Childbirth 2010;10:56.
8. Vinturache A, Moledina N, McDonald S, Slater D, Tough S. Pre-pregnancy Body Mass Index (BMI) and delivery outcomes in a Canadian population. BMC Pregnancy Childbirth 2014;14:422.
9. Ehrenberg HM, Dierker L, Milluzzi C, Mercer BM. Low maternal weight, failure to thrive in pregnancy, and adverse pregnancy outcomes. Am J Obstet Gynecol 2003;189:1726–30.
10. Frederick IO, Williams MA, Sales AE, Martin DP, Killien M. Pre-pregnancy body mass index, gestational weight gain, and other maternal characteristics in relation to infant birth weight. Matern Child Health J 2008;12:557–67.
11. Nohr EA, Vaeth M, Baker JL, Tla Sørensen, Olsen J, Rasmussen KM. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. Am J Clin Nutr 2008;87:1750–9.
12. Allen LH, Lung'aho MS, Shaheen M, Harrison GG, Neumann C, Kirksey A. Maternal body mass index and pregnancy outcome in the Nutrition Collaborative Research Support Program. Eur J Clin Nutr 1994;48(3):S68–76. Suppl.
13. Ronnenberg AG, Wang X, Xing H, et al. Low preconception body mass index is associated with birth outcome in a prospective cohort of Chinese women. J Nutr 2003;133:3449–55.
14. Rahman MM, Abe SK, Kanda M, et al. Maternal body mass index and risk of birth and maternal health outcomes in low- and middle-income countries: a systematic review and meta-analysis. Obes Rev 2015;16:758–70.
15. Dean SV, Lassi ZS, Imam AM, Bhutta ZA. Preconception care: nutritional risks and interventions. Reprod Health 2014;11(3):S3.. Suppl.
16. Schieve LA, Cogswell ME, Scanlon KS. Prepregnancy body mass index and pregnancy weight gain: associations with preterm delivery. Obstet Gynecol 2000;96:194–200.
17. Meehan S, Beck CR, Mair-Jenkins J, Leonardi-Bee J, Puleston R. Maternal obesity and infant mortality: a meta-analysis. Pediatrics 2014;133:863–71.
18. Black RE, Allen LH, Bhutta ZA, et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008;371:243–60.
19. Hult M, Tornhammar P, Ueda P, et al. Hypertension, diabetes and overweight: looming legacies of the Biafran famine. PLoS One 2010;5:e13582.
20. Sebire NJ, Jolly M, Harris JP, et al. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. Int J Obes Relat Metab Disord 2001;25:1175–82.
21. Guelinckx I, Devlieger R, Beckers K, Vansant G. Maternal obesity: pregnancy complications, gestational weight gain and nutrition. Obes Rev 2008;9:140–50.
22. O'Brien TE, Ray JG, Chan WS. Maternal body mass index and the risk of preeclampsia: a systematic overview. Epidemiology 2003;14:368–74.
23. Bhattacharya S, Campbell DM, Liston WA, Bhattacharya S. Effect of body mass index on pregnancy outcomes in nulliparous women

delivering singleton babies. BMC Public Health 2007;7:168.
24. Leddy MA, Power ML, Schulkin J. The impact of maternal obesity on maternal and fetal health. Rev Obstet Gynecol 2008;1:170–8.
25. Santangeli L, Sattar N, Huda SS. Impact of maternal obesity on perinatal and childhood outcomes. Best Pract Res Clin Obstet Gynaecol 2015;29:438–48.
26. Crane JM, White J, Murphy P, Burrage L, Hutchens D. The effect of gestational weight gain by body mass index on maternal and neonatal outcomes. J Obstet Gynaecol Can 2009;31:28–35.
27. Jensen DM, Damm P, Sørensen B, et al. Pregnancy outcome and prepregnancy body mass index in 2459 glucose-tolerant Danish women. Am J Obstet Gynecol 2003;189:239–44.
28. Torloni MR, Betrán AP, Horta BL, et al. Prepregnancy BMI and the risk of gestational diabetes: a systematic review of the literature with meta-analysis. Obes Rev 2009;10:194–203.
29. Young TK, Woodmansee B. Factors that are associated with cesarean delivery in a large private practice: the importance of prepregnancy body mass index and weight gain. Am J Obstet Gynecol 2002;187:312–8.
30. Al-Kubaisy W, Al-Rubaey M, Al-Naggar RA, Karim B. Mohd Noor NA. Maternal obesity and its relation with the cesarean section: a hospital based cross sectional study in Iraq. BMC Pregnancy Childbirth 2014;14:235.
31. Stotland NE, Hopkins LM, Caughey AB. Gestational weight gain, macrosomia, and risk of cesarean birth in nondiabetic nulliparas. Obstet Gynecol 2004;104:671–7.
32. Ekblad U, Grenman S. Maternal weight, weight gain during pregnancy and pregnancy outcome. Int J Gynaecol Obstet 1992;39:277–83.
33. Ehrenberg HM, Durnwald CP, Catalano P, Mercer BM. The influence of obesity and diabetes on the risk of cesarean delivery. Am J Obstet Gynecol 2004;191:969–74.
34. Cnattingius S, Villamor E, Johansson S, et al. Maternal obesity and risk of preterm delivery. JAMA 2013;309:2362–70.
35. Rudra CB, Frederick IO, Williams MA. Prepregnancy body mass index and weight gain during pregnancy in relation to preterm delivery subtypes. Acta Obstet Gynecol Scand 2008;87:510–7.
36. Cnattingius S, Bergström R, Lipworth L, Kramer MS. Prepregnancy weight and the risk of adverse pregnancy outcomes. N Engl J Med 1998;338:147–52.
37. Kristensen J, Vestergaard M, Wisborg K, Kesmodel U, Secher NJ. Pre-pregnancy weight and the risk of stillbirth and neonatal death. BJOG 2005;112:403–8.
38. Lawlor DA, Relton C, Sattar N, Nelson SM. Maternal adiposity—a determinant of perinatal and offspring outcomes? Nat Rev Endocrinol 2012;8:679–88.
39. Mocanu EV, Greene RA, Byrne BM, Turner MJ. Obstetric and neonatal outcome of babies weighing more than 4.5 kg: an analysis by parity. Eur J Obstet Gynecol Reprod Biol 2000;92:229–33.
40. Gaudet L, Ferraro ZM, Wen SW, Walker M. Maternal obesity and occurrence of fetal macrosomia: a systematic review and meta-analysis. BioMed Res Int 2014;2014:640291.
41. Spellacy WN, Miller S, Winegar A, Peterson PQ. Macrosomia—maternal characteristics and infant complications. Obstet Gynecol 1985;66:158–61.
42. Mamun AA, Kinarivala M, O'Callaghan MJ, Williams GM, Najman JM, Callaway LK. Associations of excess weight gain during pregnancy with long-term maternal overweight and obesity: evidence from 21 y postpartum follow-up. Am J Clin Nutr 2010;91:1336–41.
43. Thompson LA, Zhang S, Black E, et al. The association of maternal pre-pregnancy body mass index with breastfeeding initiation. Matern Child Health J 2013;17:1842–51.
44. Wojcicki JM. Maternal prepregnancy body mass index and initiation and duration of breastfeeding: a review of the literature. J Womens Health (Larchmt) 2011;20:341–7.
45. Bhavadharini B, Anjana RM, Deepa M, et al. Gestational weight gain and pregnancy outcomes in relation to body mass index in Asian Indian women. Indian J Endocrinol Metab 2017;21:588–93.
46. International Institute for Population Sciences. National Family Health survey - 4, India; 2021. Available at: http://rchiips.org/nfhs/contact.shtml. Accessed November 27, 2022.
47. Kusneniwar GN, Whelan RM, Betha K, et al. Cohort profile: the longitudinal Indian Family hEalth (LIFE) pilot study, Telangana State, India. Int J Epidemiol 2017;46:788–9. j.
48. Wang Y, Shi H, Chen L, et al. Absolute risk of adverse obstetric outcomes among twin pregnancies after in vitro fertilization by maternal age. JAMA Netw Open 2021;4:e2123634.
49. Luke B, Brown MB. Contemporary risks of maternal morbidity and adverse outcomes with increasing maternal age and plurality. Fertil Steril 2007;88:283–93.
50. Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual. Human kinetics books; 1988.
51. Lim JU, Lee JH, Kim JS, et al. Comparison of World Health Organization and Asia-Pacific body mass index classifications in COPD patients. Int J Chron Obstruct Pulmon Dis 2017;12:2465–75.
52. Jin WY, Lv Y, Bao Y, et al. Independent and combined effects of maternal prepregnancy body mass index and gestational weight gain on offspring growth at 0–3 years of age. BioMed Res Int 2016;2016:4720785.
53. WHO. Nutrition Landscape Information System (NLiS); 2021. Available at: https://apps.who.int/nutrition/publications/globaltargets2025_policybrief_lbw/en/index.html. Accessed November 27, 2022.
54. Stamnes Koepp UM, Frost Andersen L, Dahl-Joergensen K, Stigum H, Nass O, Nystad W. Maternal pre-pregnant body mass index, maternal weight change and offspring birthweight. Acta Obstet Gynecol Scand 2012;91:243–9.
55. Harville EW, Viikari JS, Raitakari OT. Preconception cardiovascular risk factors and pregnancy outcome. Epidemiology 2011;22:724–30.
56. Mascarello KC, Matijasevich A, Barros AJD, Santos IS, Zandonade E, Silveira MF. Repeat cesarean section in subsequent gestation of women from a birth cohort in Brazil. Reprod Health 2017;14:102.
57. Steen J, Loeys T, Moerkerke B, Vansteelandt S. Medflex: an R package for flexible mediation analysis using natural effect models. J Stat Soft 2017;76:1–46.
58. Fox J, Weisberg S. An R companion to applied regression. Sage. Thousand Oaks 2011.
59. Schummers L, Hutcheon JA, Bodnar LM, Lieberman E, Himes KP. Risk of adverse pregnancy outcomes by prepregnancy body mass index: a population-based study to inform prepregnancy weight loss counseling. Obstet Gynecol 2015;125:133–43.
60. Swank ML, Caughey AB, Farinelli CK, et al. The impact of change in pregnancy body mass index on cesarean delivery. J Matern Fetal Neonatal Med 2014;27:795–800.
61. Brost BC, Goldenberg RL, Mercer BM, et al. The preterm Prediction Study: association of cesarean delivery with increases in maternal weight and body mass index. Am J Obstet Gynecol 1997;177:333–7.
62. Mohammadi M, Maroufizadeh S, Omani-Samani R, Almasi-Hashiani A, Amini P. The effect of prepregnancy body mass index on birth weight, preterm birth, cesarean section, and preeclampsia in pregnant women. J Matern Fetal Neonatal Med 2019;32:3818–23.
63. Chu SY, Kim SY, Schmid CH, et al. Maternal obesity and risk of cesarean delivery: a meta-analysis. Obes Rev 2007;8:385–94.
64. Poobalan AS, Aucott LS, Gurung T, Smith WC, Bhattacharya S. Obesity as an independent risk factor for elective and emergency caesarean delivery in nulliparous women—systematic review and meta-analysis of cohort studies. Obes Rev 2009;10:28–35.
65. Driul L, Cacciaguerra G, Citossi A, Martina MD, Peressini L, Marchesoni D. Prepregnancy body mass index and adverse pregnancy outcomes. Arch Gynecol Obstet 2008;278:23–6.
66. Rode L, Nilas L, Wøjdemann K, Tabor A. Obesity-related complications in Danish single cephalic term pregnancies. Obstet Gynecol 2005;105:537–42.
67. Crane SS, Wojtowycz MA, Dye TD, Aubry RH, Artal R. Association between pre-pregnancy obesity and the risk of cesarean delivery. Obstet Gynecol 1997;89:213–6.
68. Dempsey JC, Ashiny Z, Qiu CF, Miller RS, Sorensen TK, Williams MA. Maternal pre-pregnancy overweight status and obesity as risk factors for cesarean delivery. J Matern Fetal Neonatal Med 2005;17:179–85.

69. Joy S, Istwan N, Rhea D, Desch C, Stanziano G. The impact of maternal obesity on the incidence of adverse pregnancy outcomes in high-risk term pregnancies. Am J Perinatol 2009;26:345–9.
70. Davies-Tuck M, Mockler JC, Stewart L, Knight M, Wallace EM. Obesity and pregnancy outcomes: do the relationships differ by maternal region of birth? A retrospective cohort study. BMC Pregnancy Childbirth 2016;16:288.
71. Morken NH, Klungsøyr K, Magnus P, Skjærven R. Pre-pregnant body mass index, gestational weight gain and the risk of operative delivery. Acta Obstet Gynecol Scand 2013;92:809–15.
72. Sherrard A, Platt RW, Vallerand D, Usher RH, Zhang X, Kramer MS. Maternal anthropometric risk factors for caesarean delivery before or after onset of labour. BJOG 2007;114:1088–96.
73. Phithakwatchara N, Titapant V. The effect of pre-pregnancy weight on delivery outcome and birth weight in potential diabetic patients with normal screening for gestational diabetes mellitus in Siriraj Hospital. J Med Assoc Thai 2007;90:229–36.
74. Khan N, Mozumdar A, Kaur S. Determinants of low birth weight in India: an investigation from the National Family Health Survey. Am J Hum Biol 2020;32:e23355.
75. National Health Portal. Preterm Birth. https://www.nhp.gov.in/disease/reproductive-system/female-gynaecological-diseases-/preterm-birth. Accessed July 22, 2022
76. Roy N, Mishra PK, Mishra VK, Chattu VK, Varandani S, Batham SK. Changing scenario of C-section delivery in India: understanding the maternal health concern and its associated predictors. J Family Med Prim Care 2021;10:4182–8.
77. McAuliffe FM, Killeen SL, Jacob CM, et al. Management of prepregnancy, pregnancy, and postpartum obesity from the Figo Pregnancy and Non-Communicable Diseases Committee: a FIGO (International Federation of Gynecology and Obstetrics) guideline. Int J Gynaecol Obstet 2020;151(1):16–36. Suppl.
78. Zhang C, Hediger ML, Albert PS, et al. Association of maternal obesity with longitudinal ultrasonographic measures of fetal growth: findings from the NICHD Fetal Growth Studies-Singletons. JAMA Pediatr 2018;172:24–31.
79. Khandelwal S, Reddy KS. Eliciting a policy response for the rising epidemic of overweight-obesity in India. Obes Rev 2013;14(2):114–25. Suppl.
80. Papazian T, Abi Tayeh G, Sibai D, Hout H, Melki I, Rabbaa Khabbaz L. Impact of maternal body mass index and gestational weight gain on neonatal outcomes among healthy Middle-Eastern females. PLOS ONE 2017;12:e0181255.
81. Pan Y, Zhang S, Wang Q, et al. Investigating the association between prepregnancy body mass index and adverse pregnancy outcomes: a large cohort study of 536 098 Chinese pregnant women in rural China. BMJ Open 2016;6:e011227.
82. Tsai IH, Chen CP, Sun FJ, Wu CH, Yeh SL. Associations of the pre-pregnancy body mass index and gestational weight gain with pregnancy outcomes in Taiwanese women. Asia Pac J Clin Nutr 2012;21:82–7.
83. Yang S, Peng A, Wei S, et al. Pre-pregnancy body mass index, gestational weight gain, and birth weight: a cohort study in China. PLoS One 2015;10:e0130101.
84. Gilboa SM, Correa A, Alverson CJ. Use of spline regression in an analysis of maternal prepregnancy body mass index and adverse birth outcomes: does it tell us more than we already know? Ann Epidemiol 2008;18:196–205.
85. Simhan HN, Bodnar LM. Prepregnancy body mass index, vaginal inflammation, and the racial disparity in preterm birth. Am J Epidemiol 2006;163:459–66.
86. Zhong Y, Cahill AG, Macones GA, Zhu F, Odibo AO. The association between prepregnancy maternal body mass index and preterm delivery. Am J Perinatol 2010;27:293–8.
87. Heude B, Thiébaugeorges O, Goua V, et al. Pre-pregnancy body mass index and weight gain during pregnancy: relations with gestational diabetes and hypertension, and birth outcomes. Matern Child Health J 2012;16:355–63.
88. Ovesen P, Rasmussen S, Kesmodel U. Effect of prepregnancy maternal overweight and obesity on pregnancy outcome. Obstet Gynecol 2011;118:305–12.
89. Seligman LC, Duncan BB, Branchtein L, Gaio DS, Mengue SS, Schmidt MI. Obesity and gestational weight gain: cesarean delivery and labor complications. Rev Saude Publica 2006;40:457–65.
90. Zhao R, Xu L, Wu ML, Huang SH, Cao XJ. Maternal pre-pregnancy body mass index, gestational weight gain influence birth weight. Women Birth 2018;31:e20–5.
91. Soltani H, Lipoeto NI, Fair FJ, Kilner K, Yusrawati Y. Pre-pregnancy body mass index and gestational weight gain and their effects on pregnancy and birth outcomes: a cohort study in west Sumatra, Indonesia. BMC Womens Health 2017;17:102.
92. Chung JH, Melsop KA, Gilbert WM, Caughey AB, Walker CK, Main EK. Increasing pre-pregnancy body mass index is predictive of a progressive escalation in adverse pregnancy outcomes. J Matern Fetal Neonatal Med 2012;25:1635–9.
93. Liu L, Hong Z, Zhang L. Associations of prepregnancy body mass index and gestational weight gain with pregnancy outcomes in nulliparous women delivering single live babies. Sci Rep 2015;5:12863.
94. Mastroeni MF, Czarnobay SA, Kroll C, et al. The independent importance of pre-pregnancy weight and gestational weight gain for the prevention of large-for gestational age Brazilian newborns. Matern Child Health J 2017;21:705–14.
95. Xiao L, Ding G, Vinturache A, et al. Associations of maternal pre-pregnancy body mass index and gestational weight gain with birth outcomes in Shanghai. China. Sci Rep 2017;7:41073.
96. Di Benedetto A, D'Anna R, Cannata ML, Giordano D, Interdonato ML, Corrado F. Effects of prepregnancy body mass index and weight gain during pregnancy on perinatal outcome in glucose-tolerant women. Diabetes Metab 2012;38:63–7.
97. Ogunyemi D, Hullett S, Leeper J, Risk A. Prepregnancy body mass index, weight gain during pregnancy, and perinatal outcome in a rural black population. J Matern Fetal Med 1998;7:190–3.
98. Gaillard R, Durmuş B, Hofman A, Mackenbach JP, Steegers EA, Jaddoe VW. Risk factors and outcomes of maternal obesity and excessive weight gain during pregnancy. Obesity (Silver Spring) 2013;21:1046–55.
99. Chen Z, Du J, Shao L, et al. Prepregnancy body mass index, gestational weight gain, and pregnancy outcomes in China. Int J Gynaecol Obstet 2010;109:41–4.
100. Zhang CH, Liu XY, Zhan YW, Zhang L, Huang YJ, Zhou H. Effects of prepregnancy body mass index and gestational weight gain on pregnancy outcomes. Asia Pac J Public Health 2015;27:620–30.
101. Lisonkova S, Muraca GM, Potts J, et al. Association between prepregnancy body mass index and severe maternal morbidity. JAMA 2017;318:1777–86.
102. Abenhaim HA, Kinch RA, Morin L, Benjamin A, Usher R. Effect of prepregnancy body mass index categories on obstetrical and neonatal outcomes. Arch Gynecol Obstet 2007;275:39–43.
103. Ramos GA, Caughey AB. The interrelationship between ethnicity and obesity on obstetric outcomes. Am J Obstet Gynecol 2005;193:1089–93.
104. Jaddoe VWV, Li N, Liu E, et al. Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. PLOS ONE 2013;8:e82310.
105. Kumar P, Mangla S, Kundu S. Inequalities in overweight and obesity among reproductive age group women in India: evidence from National Family Health Survey (2015−16). BMC Womens Health 2022;22:205.