# 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

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

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## 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).

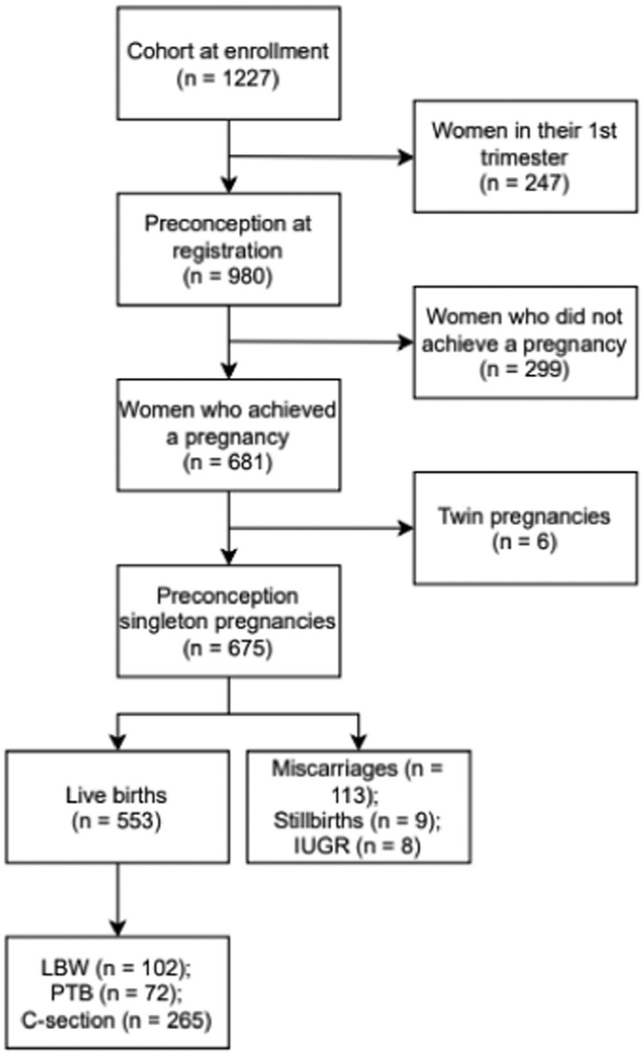
This study was approved by both University of Pittsburgh's and the Society for Health Allied Research and Education (SHARE) INDIA's institutional review boards and their ethics committees (SHARE INDIA, approved November 9, 2009; University of Pittsburgh [PRO08070108], approved September 15, 2009). Informed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

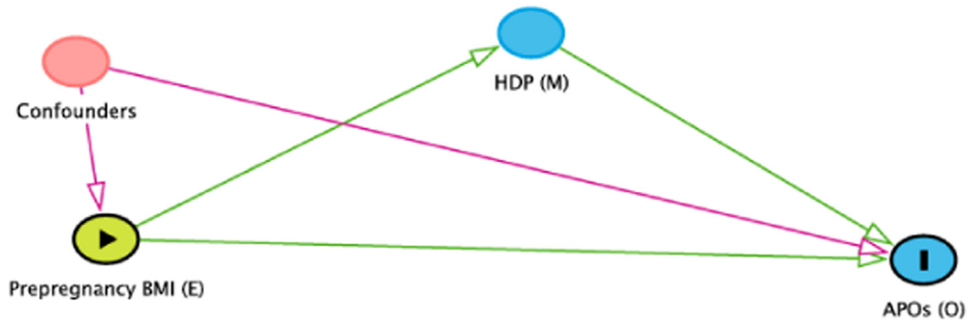
To disentangle the pathways that link prepregnancy BMI to the outcomes of interest, we also conducted exploratory analyses examining the total effect of prepregnancy BMI, the indirect effect of prepregnancy BMI operating through the mediator, hypertensive disorders of pregnancy (HDP) (including preeclampsia, 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>

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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)**

| Characteristics | Overall (n=675) | Maternal BMI: Normal 18.5–22.9 kg/m$^2$ n (%) (n=302) | Underweight <18.5 kg/m$^2$ n (%) (n=257) | Overweight 23–24.9 kg/m$^2$ n (%) (n=55) | Obese ≥25 kg/m$^2$ 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)*

| | | Maternal BMI | | | | |
|---|---|---|---|---|---|---|
| Characteristics | Overall (n=675) | Normal 18.5–22.9 kg/m$^2$ n (%) (n=302) | Underweight <18.5 kg/m$^2$ n (%) (n=257) | Overweight 23–24.9 kg/m$^2$ n (%) (n=55) | Obese ≥25 kg/m$^2$ 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. ■

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