

The impact of obesity on spontaneous and medically indicated preterm birth among adolescent mothers

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Abstract

Purpose We sought to evaluate the impact of obesity on the risk of spontaneous and medically indicated preterm birth in young women compared to adult women.

Methods Florida vital records from 2004 to 2007 were used to obtain data. The study sample consisted of 290,807 mothers of whom 4,739 were adolescent girls ≤ 15 years old; 23,228 were girls 16–17 years old; 58,196 were women 18–19 years old; and 204,644 were women 20–24 years old. Adjusted estimates for spontaneous and medically indicated preterm birth were determined based on maternal BMI and weight gain during pregnancy. Subjects were categorized by BMI as follows: class I obesity ($30.0 \leq \text{BMI} \leq 34.9$), class II obesity ($35.0 \leq \text{BMI} \leq 39.9$), class III obesity ($40 \leq \text{BMI} \leq 49.9$), and super-obese ($\text{BMI} \geq 50.0$).

Results Obese mothers had elevated risk for medically indicated preterm birth and lower risk for spontaneous preterm birth compared to non-obese mothers. Overall, the risk for spontaneous preterm birth increased in a dose-dependent fashion with younger age but no age-dependent trend was observed for medically indicated preterm birth ($P < 0.0001$). Very low weight gain (< 0.12 kg/week) during pregnancy was associated with a higher risk of spontaneous preterm birth among both non-obese and obese teenagers.

Conclusions Preterm birth is a heterogeneous entity that is mediated by obesity status and maternal age. Obesity among pregnant teenagers increases the risk for medically indicated preterm birth but not the risk for spontaneous preterm birth.

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Introduction

The etiology of preterm birth, a leading cause of perinatal mortality in the US, remains elusive amid growing concerns that the rising obesity epidemic may in the future profoundly increase the number of pregnant women afflicted by this complication. One area that has been overlooked is how obesity impacts preterm birth rates among adolescents. Obesity is now considered the leading medical condition among children resulting in an alarming increase of type II diabetes and hypertension in adolescents [1]. In addition, several studies have reported that teenage girls are at higher risk for preterm birth [2–6]. One study found that teenage girls (< 18 years) are 1.5 times as likely to experience medically indicated preterm birth, and 2.4 times as likely to

experience spontaneous preterm birth compared to women 20–34 years of age [7].

However, preterm birth appears to be a heterogeneous entity that could be clinically classified into spontaneous and medically indicated subtypes. Spontaneous and medically induced preterm birth appear to result from different etiologies as previous research has shown that obesity is protective for spontaneous preterm birth, but a risk factor for medically indicated preterm birth [8–10]. Weight gain during pregnancy is another important parameter that influences the effects of BMI on birth outcomes and evidence has shown that inadequate weight gain late in pregnancy may predispose teenage as well as adult mothers to deliver preterm [11].

Although several studies have examined the influence of obesity on adverse birth outcomes in the general as well as the adult population of pregnant women, there is very little information on its impact in teen mothers. To our knowledge, this is the first study that seeks to assess the effect of obesity on subtypes of preterm birth among teenage mothers. The study is guided by the following hypotheses:

1. High BMI worsens the risk for both medically indicated and spontaneous preterm birth.
2. The risk for medically indicated and spontaneous preterm birth among adolescent mothers correlates positively with body mass index (BMI) in a dose-dependent fashion.
3. Gestational weight gain modifies the risk for the two phenotypes of preterm birth associated with high BMI among teen mothers.

Methods

We used Florida vital records from the years 2004 to 2007 inclusively since the addition of pre-pregnancy BMI to US birth certificates was only started in the State of Florida in 2004. From an initial population of 917,449 live births, we sequentially excluded: 2542 (0.28%) mothers whose infants had gestational ages outside the range of 20–44 weeks, 28727 (3.4%) mothers whose infants were not singleton, 92,006 (10.4%) mothers who had missing pre-pregnancy BMI, 30,798 (3.9%) mothers who were not white, black, or Hispanic, and 427,569 (51.5%) mothers who were not 24 years of age or younger. The final study sample comprised 4,739 (1.6%) girls ≤ 15 years old, 23,228 (8.0%) girls 16–17 years old, 58,196 (20.0%) women 18–19 years old, and 204,644 (70.4%) women 20–24 years old, for a total of 290,807 records.

Obese and non-obese groups were created based on BMI values calculated as pre-pregnancy weight (kg)/height (m)² [12]. Mothers with BMI values less than 30 kg/m² were

classified as non-obese, while those with BMI values greater than or equal to 30 kg/m² were classified as obese. Further classifications by BMI values were made as follows: class I obesity ($30.0 \leq \text{BMI} \leq 34.9$), class II obesity ($35.0 \leq \text{BMI} \leq 39.9$), class III obesity ($40 \leq \text{BMI} \leq 49.9$), and super-obese ($\text{BMI} \geq 50.0$) [12–17]. Mothers were also categorized according to weight gain during pregnancy into the following sub-classes: <0.12 kg/week (very low), 0.12–0.22 kg/week (low), 0.23–0.68 kg/week (moderate), 0.69–0.79 kg/week (high), and >0.79 kg/week (very high) [18].

The main outcome of interest was preterm birth, defined as delivery occurring at less than 37 weeks of gestation. Gestational age was largely based on the interval between the last menstrual period and the date of delivery of the baby. When the menstrual estimate of gestational age was inconsistent with the birth weight (e.g., very low birth weight at term), a clinical estimate of gestational age on the vital records was used instead [19, 20].

Two clinical subtypes of preterm birth were considered for analysis: medically indicated preterm birth and spontaneous preterm birth. We defined preterm birth as spontaneous if labor was present and if the women delivered preterm, or if premature rupture of the membranes occurred. Labor was considered present if the birth record indicated one or more of the following conditions: vaginal birth without an induction of labor, tocolysis, cephalopelvic disproportion, precipitated labor, prolonged labor, dysfunctional labor, or vaginal birth after cesarean [21]. Medically indicated preterm birth was defined as delivery that required either an induction of labor or a pre-labor cesarean or both [21]. Covariates that were considered in the analyses include: parity (nulliparous vs. multiparous), race (non-Hispanic black, non-Hispanic white, and Hispanic), tobacco use (yes vs. no), alcohol use (yes vs. no), and adequacy of prenatal care (yes vs. no). The revised graduated index algorithm, a proven method for evaluating the degree of prenatal care utilization among high-risk women, was used to assess the adequacy of prenatal care in the study population [22, 23]. The index is based on the trimester when prenatal care began, the number of prenatal visits attended, and the gestational age of the infant at delivery. Pregnancy complications that were adjusted for in the analyses include: pre-eclampsia (defined as the presence of elevated blood pressure ($>140/90$) developing after 20 weeks of gestation with proteinuria), eclampsia (pre-eclampsia with seizures), anemia [defined as hematocrit (Hct) values less than 30% or hemoglobin (Hgb) levels less than 10 g/dL], gestational diabetes (defined as glucose intolerance with onset or first recognition during pregnancy), and hypertension (the presence of elevated blood pressure before 20 weeks of gestation).

The chi-square test was used to evaluate differences in socio-demographic characteristics and maternal pregnancy

complications between mothers across age groups. We applied chi-square for trend to assess dose–response relationships [24]. Multivariate logistic regression was used to obtain adjusted estimates for the association among maternal age, spontaneous preterm birth, medically indicated preterm birth, obesity status and weight gain during pregnancy. Two models were constructed for each preterm subtype and overall preterm: one that included socio-demographics, and the second which included socio-demographics and pregnancy complications. This was done to determine the impact of potential confounding by pregnancy complications on preterm delivery subtypes. For all logistic models, non-obese mothers 20–24 years were used as the referent group.

In a separate analysis, adjusted estimates were also obtained for the risk of spontaneous preterm birth by maternal age, obesity status and pregnancy weight gain. Two models were constructed as described above and the referent group was non-obese women aged 20–24 who had moderate weight gain during pregnancy (0.23 and 0.68 kg/week). Logistic regression models were also constructed to obtain adjusted estimates for the risk of preterm birth (overall, spontaneous, and medically indicated) by obesity subtype. SAS (SAS Institute, Inc., Cary, North Carolina, version 9.2) was used to conduct all analyses, and all tests of hypothesis were two tailed with a type 1 error rate fixed at 5%. The study was approved by the Institutional Review Board at the University of South Florida.

Results

The overall rate of preterm birth in the study population was 9.4% ($N = 27,217$). In total, 6.5% ($N = 18,1858$) of mothers experienced spontaneous preterm birth, while 2.9% ($N = 8,359$) of mothers experienced medically indicated preterm birth. Obese mothers had higher rates of medically indicated preterm birth [3.6 vs. 2.7% (P value < 0.0001)] and lower rates of spontaneous preterm birth [5.3 vs. 6.7% (P value < 0.0001)] compared to non-obese mothers.

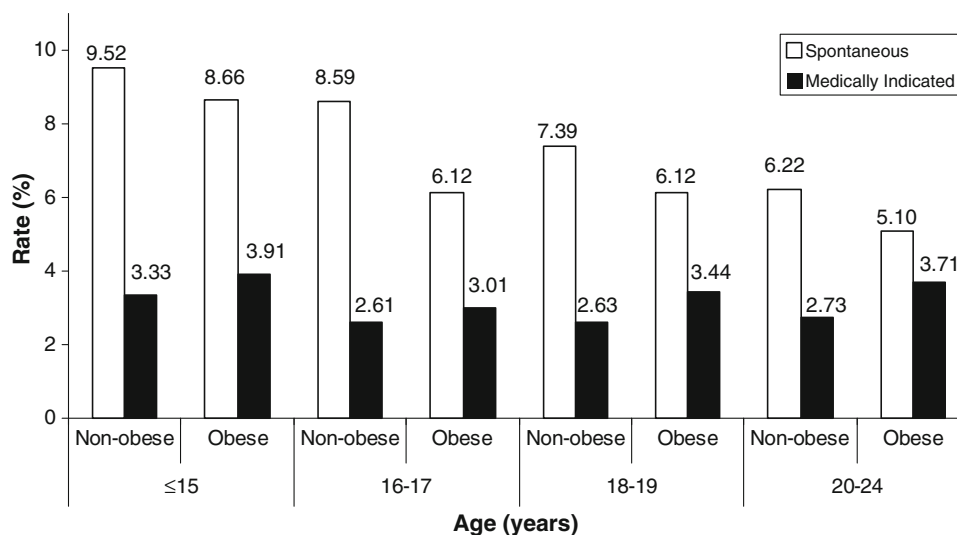
Table 1 compares socio-demographic characteristics and pregnancy complications across maternal age groups. The rate of obesity ($BMI \geq 30$) rose positively with age. Smoking and alcohol use also increased with age, as well as adequate prenatal care. The number of mothers suffering from anemia remained fairly constant across age groups; however, diabetes and hypertension increased with increasing maternal age. Pre-eclampsia and eclampsia both decreased with age. Rates for both spontaneous and medically indicated preterm were highest among girls aged 15 and younger [9.5% (P value < 0.0001) and 3.4% (P value = 0.003), respectively].

Figure 1 gives an overview of the rates of spontaneous and medically indicated preterm birth across age groups and obesity status. Rates of medically indicated preterm birth were higher in obese mothers compared to non-obese mothers in all age categories; however, non-obese mothers had consistently higher rates of spontaneous preterm birth

Table 1 Socio-demographics and pregnancy complications according to maternal age

Socio-demographics and pregnancy complications	≤ 15 (years) $N = 4739$ (%)	16–17 (years) $N = 23,228$ (%)	18–19 (years) $N = 58,196$ (%)	20–24 (years) $N = 204,644$ (%)	P value
Smoking	3.00	7.00	10.26	10.71	< 0.0001
Adequate prenatal care	17.98	23.34	26.89	31.99	< 0.0001
Alcohol use	0.17	0.22	0.26	0.33	0.003
Obesity ($BMI \geq 30$)	7.55	9.43	13.65	19.79	< 0.0001
Nulliparity	94.49	83.60	68.34	41.15	< 0.0001
Race					
White	24.37	33.74	40.87	45.20	
Black	41.63	32.59	28.66	23.74	< 0.0001
Hispanic	33.99	33.67	30.47	31.06	
Anemia	2.47	2.54	2.49	2.07	< 0.0001
Diabetes	0.19	0.20	0.29	0.49	< 0.0001
Hypertension	0.40	0.51	0.62	0.81	< 0.0001
Pre-eclampsia	6.08	5.63	5.23	4.59	< 0.0001
Eclampsia	0.42	0.26	0.20	0.17	< 0.0001
Preterm					
Spontaneous	9.45	8.36	7.22	6.00	< 0.0001
Medically indicated	3.38	2.65	2.74	2.93	0.003
All preterm	12.83	11.01	9.96	8.93	< 0.0001

Fig. 1 Rates of spontaneous and medically indicated preterm birth according to obesity status and maternal age



compared to obese mothers in each age group. Overall, spontaneous preterm birth rates increased in a dose-dependent fashion with younger age but no age-dependent trend was observed for medically indicated preterm birth. Adjusted estimates for the risk of overall preterm birth and related preterm subtypes by obesity and maternal age are presented in Table 2. Among non-obese mothers, those aged 15 and younger were 42% more likely to experience both types of preterm birth compared to 20–24 year olds. This risk decreased progressively as teenagers approached their twenties. Obese teenagers aged 15 and younger had a 37% increased risk for all preterm deliveries compared to non-obese 20–24 year olds. However, we did not detect a trend with varying age among obese teenagers for all preterm birth. In model I (Table 2), the risk for spontaneous preterm birth was greater in non-obese than obese teenagers, and increased with younger age ($P < 0.0001$). This trend was least pronounced after adjusting for pregnancy complications (Model II). The risk for medically indicated preterm birth was highest among obese mothers, yet the risk was only significant for 18–19 year olds and 20–24 year olds [Model I: OR = 1.24 (1.10–1.41), OR = 1.34 (1.27–1.43), respectively]. Among both obese and non-obese teenage and adult mothers, the increased risk for medically indicated preterm birth was either significantly blunted or eliminated once pregnancy complications were accounted for.

Adjusted estimates for the risk of preterm birth in teenage mothers by obesity subtype are shown in Table 3. The results demonstrate that obesity was a risk factor for medically indicated preterm birth but not for spontaneous preterm birth. The risk for medically indicated preterm birth was significant for class II obesity and more severe subtypes increasing in a dose–effect pattern ($P < 0.0001$). Super-obese teenage mothers were about three times as

likely to experience medically indicated preterm birth compared to non-obese 20–24 year olds. Most of the increased risk was attributable to pregnancy complications as depicted in Model II (Table 3).

Adjusted estimates for the risk of spontaneous preterm birth among teenage mothers by obesity status across categories of gestational weight gain are summarized in Table 4. Overall, non-obese mothers had the highest risk for spontaneous preterm birth in all weight gain categories. Teenagers who gained the least weight in pregnancy (<0.12 kg/week) had the highest risk for spontaneous preterm birth compared to non-obese 20–24 year olds with moderate weight gain. Non-obese teenagers with moderate weight gain were 15% more likely to experience spontaneous preterm birth compared to non-obese 20–24 year olds with similar weight gain.

Discussion

In this study, we found an elevated increase of spontaneous preterm birth among non-obese teenage mothers, while medically indicated preterm birth was more prevalent among obese mothers. Our findings correlate with previous research that indicates that preterm birth is a heterogeneous entity [8, 9]. The results of this study imply that preterm birth subtypes are disparately modified in a dose-dependent manner by body mass index. Since spontaneous preterm birth is two to three times more prevalent than medically indicated preterm birth in this study population, the effect of BMI on medically indicated preterm birth would have been masked if preterm subtypes had not been analyzed separately.

By dividing women into obesity subgroups, we were able to identify that obesity had a dose-dependent effect on

Table 2 Adjusted estimates for risk of spontaneous and medically indicated preterm birth by maternal age and obesity status

Maternal age (years)	Model I				Model II							
	All preterm		Spontaneous		Medically indicated		All preterm		Spontaneous		Medically indicated	
	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)
≤15	1.42 (1.30–1.56) N = 563	1.37 (1.00–1.88) N = 45	1.48 (1.33–1.65) N = 417	1.33 (0.92–1.93) N = 31	1.26 (1.06–1.50) N = 146	1.46 (0.85–2.50) N = 14	1.36 (1.24–1.50) N = 563	1.22 (0.89–1.68) N = 45	1.46 (1.31–1.62) N = 417	1.25 (0.86–1.82) N = 31	1.01 (1.01–1.015) N = 146	1.02 (1.01–1.04) N = 14
16–17	1.20 (1.15–1.27) N = 2,357	0.96 (0.83–1.11) N = 200	1.31 (1.24–1.39) N = 1,807	0.91 (0.76–1.09) N = 134	0.95 (0.86–1.04) N = 550	1.07 (0.84–1.38) N = 66	1.17 (1.11–1.23) N = 2,357	0.86 (0.74–1.00) N = 200	1.29 (1.22–1.37) N = 1,807	0.87 (0.72–1.03) N = 134	0.82 (0.82–0.82) N = 550	0.78 (0.78–0.79) N = 66
18–19	1.11 (1.07–1.15) N = 5,038	1.05 (0.97–1.13) N = 759	1.17 (1.13–1.22) N = 3,714	0.96 (0.87–1.06) N = 486	0.96 (0.90–1.03) N = 1,324	1.24 (1.10–1.41) N = 273	1.09 (1.06–1.13) N = 5,038	0.95 (0.88–1.03) N = 759	1.16 (1.12–1.21) N = 3,714	0.92 (0.84–1.01) N = 486	0.88 (0.88–0.88) N = 1,324	0.95 (0.95–0.95) N = 273
20–24	Referent	0.97 (0.94–1.01) N = 3,568	Referent	0.81 (0.77–0.85) N = 2,064	Referent	1.34 (1.27–1.43) N = 1,504	Referent	0.89 (0.85–0.92) N = 3,568	Referent	0.78 (0.74–0.81) N = 2,064	Referent	1.03 (1.03–1.04) N = 1,504

Reference group is non-obese 20–24 year olds. Model I is adjusted for socio-demographics. Model II is adjusted for socio-demographics and pregnancy complications
N = number of outcomes

both the risk for spontaneous and medically indicated preterm birth. Obesity was shown to be protective for spontaneous preterm birth, while it was a risk factor for medically indicated preterm birth. Super-obese teenagers were 2.6 times as likely to experience medically indicated preterm birth compared to non-obese adult women. We found that age alone increases the risk for spontaneous preterm birth, as non-obese teenagers had a 21% increased risk of spontaneous preterm delivery compared to non-obese adult women. This was consistent with previous research that indicated an increased risk for preterm labor among teenagers [25].

Our results also demonstrate that weight gain is an important indicator of risk for spontaneous preterm birth. Non-obese women who gained less than 0.23 kg/week were significantly more likely to experience spontaneous premature delivery compared to non-obese 20–24 year olds with moderate weight gain. Interestingly, obese teenage mothers who gained little weight (<0.23 kg/week) fared significantly better than non-obese teenage mothers in the same weight gain category. In addition, non-obese teenage mothers who gained 0.69–0.79 kg/week benefitted from the additional weight gain as their risk for spontaneous preterm delivery was the lowest among non-obese teenagers. However, gaining more than 0.79 kg/week did not appear to offer any additional benefit and was possibly detrimental. This was difficult to assess as odds ratios in the highest weight gain categories were not significant. Previous research has shown that inadequate weight gain (<0.4 kg/week) by adolescent mothers in late pregnancy is associated with an increase in preterm delivery [11]. Most importantly, this finding persisted even when overall weight gains did not fall below clinical standards [11]. This has also been found to be true for adult women [26, 27]. Identifying an optimal weight gain during pregnancy is an area that deserves more attention, especially in light of evidence that preterm delivery may be dependent on this factor. Nutritional recommendations need to be tailored to the age and BMI of the pregnant mother. Clinical standards for optimal weight gain may need to be re-evaluated by trimester and not measured as an overall assessment for the entire pregnancy.

According to our results, the younger a teenage mother is the more likely she is to experience spontaneous preterm delivery. Obesity appears to mediate this risk in a protective manner. This finding supports the theory that nutritional deficiency is directly implicated in the development of spontaneous preterm birth. Teenagers are still in the process of growing and this could mean that they are competing with the fetus for nutrients [11, 28]. Teenagers in developed countries often have energy-dense, micronutrient-poor diets that are especially deficient in folate, iron and vitamin D [29–31]. Previous research has shown that lower

Table 3 Adjusted estimates for risk of preterm birth among teenage mothers by obesity subtype

Obesity subtype	Model I			Model II		
	All preterm OR (95% CI)	Spontaneous OR (95% CI)	Medically indicated OR (95% CI)	All preterm OR (95% CI)	Spontaneous OR (95% CI)	Medically indicated OR (95% CI)
Non-obese	1.15 (1.11–1.18)	1.22 (1.18–1.27)	0.98 (0.92–1.03)	1.13 (1.09–1.16)	1.21 (1.17–1.25)	0.93 (0.930–0.932)
Class I	1.03 (0.95–1.12)	1.01 (0.92–1.12)	1.07 (0.93–1.23)	0.95 (0.88–1.04)	0.98 (0.88–1.08)	0.91 (0.907–0.913)
Class II	1.05 (0.91–1.20)	0.89 (0.75–1.05)	1.42 (1.16–1.75)	0.94 (0.82–1.08)	0.84 (0.71–0.99)	1.13 (1.12–1.14)
Class III	0.98 (0.80–1.22)	0.73 (0.55–0.98)	1.57 (1.16–2.12)	0.83 (0.67–1.03)	0.68 (0.51–0.90)	1.11 (1.105–1.121)
Super-obese	1.56 (0.84–2.89)	1.11 (0.48–2.57)	2.60 (1.13–6.02)	1.16 (0.61–2.18)	0.95 (0.41–2.21)	1.56 (1.53–1.60)

Reference group is non-obese 20–24 year olds. Model I is adjusted for socio-demographics only. Model II is adjusted for socio-demographics and pregnancy complications

Table 4 Adjusted estimates for the risk of spontaneous preterm birth among teenage mothers by obesity status across gestational weight gain categories

Pregnancy weight gain (kg/week)	Model I		Model II	
	Non-obese OR (95% CI)	Obese OR (95% CI)	Non-obese OR (95% CI)	Obese OR (95% CI)
<0.12 (very low)	2.56 (2.31–2.85)	1.30 (1.05–1.61)	2.61 (2.35–2.90)	1.29 (1.05–1.60)
0.12–0.22 (low)	2.12 (1.97–2.29)	1.12 (0.91–1.37)	2.16 (2.00–2.33)	1.11 (0.90–1.37)
0.23–0.68 (moderate)	1.14 (1.10–1.19)	0.86 (0.77–0.96)	1.15 (1.10–1.19)	0.82 (0.73–0.92)
0.69–0.79 (high)	0.87 (0.74–1.02)	1.02 (0.66–1.57)	0.83 (0.71–0.97)	0.94 (0.61–1.45)
>0.79 (very high)	1.18 (0.99–1.41)	1.04 (0.66–1.64)	1.09 (0.91–1.30)	0.95 (0.60–1.49)

Reference group is non-obese 20–24 year olds with moderate weight gain (0.23–0.68 kg/week). Model I is adjusted for socio-demographics. Model II is adjusted for socio-demographics and pregnancy complications

intakes of calories, proteins, vitamins, and minerals are associated with spontaneous preterm birth [11, 28, 32]. One study determined that despite similar nutritional intakes by teenage mothers compared to adult women, the measured skinfold thickness (representing caloric accumulation) of infants born to teenage mothers was less than that of older women [28]. Optimal pregnancy weight gain may differ between adolescent girls and adult women.

Another hypothesis that deserves attention is the observation that obese women have longer cervical lengths than non-obese women [9, 33]. This may explain the protective aspect of obesity on spontaneous preterm birth, as cervical length is an important predisposing factor [9, 33].

By contrast our findings demonstrate that medically indicated preterm birth is more likely to occur among obese women and that this elevated risk is due mostly to an increased risk of pregnancy complications. Previous research has linked obesity in pregnancy to a number of medical conditions which can lead to preterm delivery such as pre-eclampsia, chronic and gestational diabetes, and hypertension [34–37]. Hypertension alone has been shown to result in an eightfold increased risk of preterm delivery [36]. Numerous metabolic and biochemical disturbances occur with obesity including oxidative stress, inflammation,

insulin resistance, and altered endothelial and vascular functioning [38–43]. Inflammation has been given much attention recently as a possible causal agent for preterm birth [38–43]. Pre-eclampsia, diabetes, and hypertension are all conditions that are related to lipid-induced inflammatory responses [39, 43].

Possible limitations of this study include recall bias or misclassification bias. Since we determined gestational age from the date of the last menstrual period, there may be errors in recall. However, this would result in non-differential misclassification and bias towards the null. In addition, defining medically indicated preterm birth was dependent on records including the presence of certain medical conditions and if these were misreported then errors in classification would have occurred. Again, this would result in non-differential misclassification and underestimation of the true association.

Preterm birth is a heterogeneous entity that is mediated by obesity status and maternal age. Obesity is associated with decreased rates of spontaneous preterm birth, while it is a risk factor for medically indicated preterm birth. The growing obesity epidemic may contribute to a shift in the future from spontaneous preterm birth to medically indicated preterm birth. Nutritional and weight gain recommendations

for teenage mothers may need to be re-evaluated as teenagers may not have the same nutritional requirements as adult women. Additionally, teenage mothers may significantly lower their risk for medically indicated preterm birth by maintaining healthy BMI ranges. This is especially important for super-obese teenage mothers as they are at the highest risk due to the dose-dependent effect of obesity on medically indicated preterm birth. However, interventions aimed at reducing BMI in obese teenagers may not be beneficial for lowering the risk of spontaneous preterm birth. Future studies, such as prospective studies, need to be conducted to confirm these results.

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Conflict of interest statement The authors declare that there is no conflict of interest.

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