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Maternal obesity and risk of cesarean delivery: a meta-analysis

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Summary

Despite numerous studies reporting an increased risk of cesarean delivery among overweight or obese compared with normal weight women, the magnitude of the association remains uncertain. Therefore, we conducted a meta-analysis of the current literature to provide a quantitative estimate of this association. We identified studies from three sources: (i) a PubMed search of relevant articles published between January 1980 and September 2005; (ii) reference lists of publications selected from the search; and (iii) reference lists of review articles published between 2000 and 2005. We included cohort designed studies that reported obesity measures reflecting pregnancy body mass, had a normal weight comparison group, and presented data allowing a quantitative measurement of risk. We used a Bayesian random effects model to perform the meta-analysis and meta-regression. Thirty-three studies were included. The unadjusted odd ratios of a cesarean delivery were 1.46 [95% confidence interval (CI): 1.34–1.60], 2.05 (95% CI: 1.86–2.27) and 2.89 (95% CI: 2.28–3.79) among overweight, obese and severely obese women, respectively, compared with normal weight pregnant women. The meta-regression found no evidence that these estimates were affected by selected study characteristics. Our findings provide a quantitative estimate of the risk of cesarean delivery associated with high maternal body mass.

Keywords: Cesarean delivery, maternal obesity, pregnancy, reproductive outcomes.

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Introduction

In 1996, the US cesarean delivery rate began to rise, ending a decline that began in 1989. By 2004, the overall cesarean delivery rate peaked at 29.1%, the highest rate ever reported in the United States (1). Changes in demographics, physician practices and maternal choice have influenced the rate of cesarean deliveries, but changes in maternal weight also may be having a significant effect. Numerous studies in the United States and elsewhere have reported an increased risk of cesarean delivery among overweight or obese women compared with lean or normal weight women. Given the rapid increase in obesity prevalence in the United States during the past 2 decades to where about 30% of women of reproductive age are obese (2), even a modest effect of obesity on cesarean delivery rates could have substantial population impact.

Despite the number and consistency of studies reporting a higher risk of cesarean delivery with increasing weight or body mass index (BMI), the magnitude of the association remains uncertain (3,4). This information is critical to estimate the impact of obesity on health and resources; therefore, we conducted a systematic review and meta-analysis of the current literature to provide a quantitative

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estimate of the association between maternal obesity and risk of cesarean deliveries.

Sources

Search process

Using recommendations from the Meta-analysis of Observational Studies in Epidemiology guidelines (5), we identified studies for possible inclusion in this analysis using three sources. First, we searched PubMed from January 1980 to September 2005 using the following criteria:

(overweight or obesity or BMI or body mass index or weight gain) AND (pregnancy or pre-pregnancy) AND (risks or effects or complications).

From this search, we retrieved the full text for abstracts that mentioned a relationship between maternal obesity and pregnancy complications from a case–control or cohort study. Studies that reported on cesarean delivery as an outcome (both elective and emergency) were included for consideration. Because there was only one case–control study selected, we excluded that study from this analysis and only focused on studies with a cohort design. We also excluded five studies that only examined vaginal birth after cesarean (VBAC). Studies that did not have full text in English were translated for review.

Second, we manually reviewed the reference lists of the publications previously retrieved and obtained the entire text of studies that potentially could be included in the meta-analysis. Finally, we obtained review articles on obesity and maternal outcomes published between 2000 and 2005 and searched their reference lists for additional potential studies. If there were multiple articles on cesarean delivery from the same study population, we only included the most current publication. We did not attempt to locate any unpublished studies.

Studies that were considered potentially eligible were then evaluated for inclusion in the meta-analysis if they met the following criteria:

1. Reported obesity measures (maternal weight, percent over ideal weight, BMI) reflecting status preceding any significant pregnancy weight gain (i.e. was measured or reported pre-pregnancy or during the first trimester or first prenatal visit);
2. Had a comparison group of normal weight women;
3. Presented data in tables, figures, or the text that allowed for a quantitative measurement of obesity and risk of cesarean delivery.

Data abstraction

All articles were read and abstracted by two reviewers using the same structured data form. A final abstraction form was compiled from the two forms after correction or resolution of any differences between reviewers. Abstracted information included study design, setting, location, time period, number and characteristics of study subjects, the source and categorization of obesity measures, the source(s) of the outcome (e.g. birth certificates, medical records), and statistical methods, including adjustment factors.

Statistical analysis

For each study, we constructed separate 2×2 tables to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) of cesarean delivery for each BMI/weight category analysed (i.e. overweight, obese, and severely obese vs. normal BMI/weight respectively). Because about one-third of the studies did not present adjusted ORs, only crude ORs were used in the primary meta-analysis. However, we did perform sensitivity analyses combining adjusted ORs when available. BMI/weight categories used varied somewhat among the studies. In general, we used the BMI/weight categories for normal, overweight, obese and severely obese as defined by each study (Table 1); in three of the studies, narrow intervals were collapsed into grouping that more appropriately fit normal, overweight, obese and severely obese categories (e.g. 19.8–22.0 and 22.1–24.9 were combined into one 19.8–24.9 normal weight category). Sources for information on type of delivery, pre-pregnancy BMI/weight and other variables varied among studies, but most frequently were medical records or perinatal/obstetric clinical databases (Table 1). All studies but two (4,6) included both primary and repeat cesarean deliveries.

Meta-analyses combining the ORs across studies were conducted using both the DerSimonian-Laird and Bayesian random effects models (7,8). Both models incorporate within and between-study variances. In addition, the Bayesian model incorporates uncertainty in the between-study variance which gives slightly wider CIs. Because the point estimates of the two models were similar, we chose to use the more conservative Bayesian estimates.

The Bayesian model assumes that the counts in the exposed and unexposed groups follow binomial distributions with different mean probabilities. These means are modelled on the logit scale so that their difference represents the log OR. The model is therefore a hierarchical logistic regression. The mean and variance of the log OR are random variables in the Bayesian model. To represent our lack of prior knowledge about the value of these hyperparameters, we used diffuse priors that encompassed a wide range of possible values. For means and regression coefficient parameters, these were normal distributions with mean 0 and extremely large variance 10^7; for the variance parameters, we used inverse gamma (1.0, 0.1)

Table 1 Characteristics of cohort studies examining the relationship between body mass index (BMI) and cesarean deliveries

Citation	Country study period	Type and source of cohort	Cohort size	CD rate normal weight women (%)	Exclusion criteria		BMI/weight categories			
					DM	GDM	Normal	Overweight	Obese	Severely obese
Baeten *et al.* (14)	United States 1992–1996	Prospective cohort from state birth certificate records.	96 801	16.6	No	No	20–24.9	25–29.9	≥30	NA
Baker *et al.* (15)	Denmark (years not given)	Prospective cohort from national birth registry.	3 768	9.8	Yes	Yes	18.5–24.9	25–29.9	≥30	NA
Bianco *et al.* (16)	United States 1988–1995	Retrospective cohort from a medical centre's perinatal database.	11 926	15.9	No	No	19–27	NA	>35	NA
Cedergren *et al.* (17)	Sweden 1992–2001	Prospective cohort from national birth registry.	621 221	10.9	No	No	19.8–26	NA	29.1–35	>35
Crane *et al.* (6)	United States 1994–1995	Retrospective cohort from a regional perinatal data system.	16 391	20.2	No	No (adj)	<29	NA	29–39.9	≥40
Dempsey *et al.* (18)	United States 1996–2000	Prospective cohort from prenatal care clinics.	738	23.1	Yes	No	20–24.9	25–29.9	≥30	NA
Dietz *et al.* (4)	United States 1998–2000	Retrospective cohort based on a multistate surveillance system from birth certificates.	24 423	20.1	No (adj)	No (adj)	19.8–26	26.1–29.9	29.1–34.9	≥35
Djrolo, 2002	France 1999	Retrospective cohort from obstetric clinics.	323	21.1	No	No	20–24.9	25–29.9	≥30	NA
Edwards *et al.* (20)	United States 1977–1993	Retrospective cohort from medical centre.	1 343	9.1	No (adj)	No (adj)	19.8–26	NA	>29	NA
Ehrenberg *et al.* (21)	United States 1997–2001	Retrospective cohort from tertiary centre perinatal database.	12 303	7.7	No (adj)	No (adj)	20–25	25–30	>30	NA
Galtier-Dereure *et al.* (22)	France 1990–1993	Retrospective cohort from obstetrics department.	166	9.3	Yes	No	8–24.9	25–29.9	30–34.9	≥35
Garbaciak *et al.* (10)	United States 1982	Prospective cohort from a perinatal network of maternal and infant medical records.	9 667	10.4	No	No	85–120%	120–150%	>150%	NA
Grossetti *et al.* (23)	France 2002–2003	Retrospective cohort from maternity wards.	2 496	15.4	No	No	20–25	NA	NA	>40
Hamon *et al.* (13)	France 2002	Retrospective cohort from obstetric clinics.	192	2.1	Yes	Yes	≤25	NA	>30	NA
Jensen *et al.* (24)	Denmark 1993–1998	Retrospective cohort from a hospital database.	1 699	6.0	No	No	20–24.9	25–29.9	≥30	NA
Jensen *et al.* (11)	Denmark 1992–1996	Prospective cohort from university hospital clinics.	2 459	14.7	Yes	Yes	18.5–24.9	25–29.9	≥30	NA

Table 1 *Continued*

Citation	Country study period	Type and source of cohort	Cohort size	CD rate normal weight women (%)	Exclusion criteria		BMI/weight categories			
					DM	GDM	Normal	Overweight	Obese	Severely obese
Johnson *et al.* (25)	United States 1987–1989	Prospective cohort from prenatal clinics.	3 191	12.0	No (adj)	No (adj)	19.8–26.0	27–29	>29	NA
Kaiser and Kirby (12)	United States 1994–1998	Retrospective cohort from medical midwifery clinics.	1 881	4.1	Yes	Yes	19.8–26	26.1–28.9	≥29	NA
Kumari (26)	United Arab Emirates 1996–1998	Retrospective cohort from maternity units.	488	9.3	No	No	22–28	NA	NA	≥40
Le *et al.* (27)	France 1988–1990	Retrospective cohort from obstetric clinics.	140	8.6	No	No	≤25	NA	≥30	NA
Lombardi *et al.* (3)	United States 1990–2000	Prospective cohort from obstetric clinics.	730	40.3	No	No	20–25	NA	≥30	NA
Michlin *et al.* (28)	Israel 8/1995–11/1995	Retrospective cohort from hospital clinics.	334	10.8	No	No	19.8–26	NA	>29	NA
Ogunyemi *et al.* (29)	United States 1990–1995	Retrospective cohort of low income African–American women from hospital clinics.	582	15.0	No	No	19.8–26	26.1–29	>29	NA
Ramos and Caughey (30)	United States 1981–2001	Retrospective cohort from medical centre clinics.	22 685	17.0	No	No (adj)	19.8–26	26.1–29	>29	NA
Ray *et al.* (31)	Canada 1993–1998	Retrospective cohort from hospital clinics.	536	39.0	No	No	20–24.9	25–29.9	≥30	NA
Rode *et al.* (32)	Denmark 1998–2001	Prospective cohort from hospital clinics.	8 092	11.3	No	No	<25	25–29	≥30	NA
Rosenberg *et al.* (33)	United States 1998–1999	Retrospective cohort from state birth certificate file.	213 208	19.6	No	No	100–149lbs	150–199 lb	200–299 lb	≥300 lb
Rossner and Ohlin (34)	Sweden (year not given)	Retrospective cohort from a maternity ward clinics.	2 295	11.4	No	No	20–25.9	>26	NA	NA
Sebire *et al.* (35)	United Kingdom 1989–1997	Retrospective cohort from a maternity ward database.	325 395	4.1	No (adj)	No (adj)	20–24.9	25–29.9	≥30	NA
Szymanska *et al.* (36)	Poland (year not given)	Retrospective cohort from obstetric clinics.	1 442	20.0	No	No	≤27	>27	NA	NA
Vahratian *et al.* (37)	United States 1995–2002	Prospective cohort from prenatal care clinics.	641	26.5	No	No	19.8–26	26.1–29	>29	NA
Valentin *et al.* (38)	Denmark 1996–1998	Prospective cohort from medical clinics.	722	9.0	No	No	20–25	25–30	>30	NA
Young and Woodmansee (39)	United States 1993–2001	Retrospective cohort from private obstetric practice.	3 376	18.4	No	No	20–24.9	25–30	>30	NA

CD, cesarean delivery; DM, diabetes mellitus; GDM, gestational diabetes mellitus; NA, not available.

distributions. To compute the Bayesian estimates, we used a Markov chain Monte Carlo (MCMC) algorithm running three parallel chains and monitoring convergence with the Gelman-Rubin diagnostic (9). Upon convergence, which generally occurred within 1000 runs, we saved 15 000 samples from each chain to estimate posterior distributions of model parameters. The MCMC algorithm used is described in greater detail by Schmid *et al*. (8).

We also conducted a Bayesian meta-regression analysis to assess whether the relationship between obesity and cesarean delivery varied by certain study characteristics. In these models, the log ORs are related to the study characteristics by a linear regression model. These included date of publication (1985–1999, 2000–2003, 2004–2005), study location (the United States vs. all other countries), parity (nulliparous vs. multiparous), type of data collection (prospective vs. retrospective) and cesarean delivery rate among normal weight women.

In addition, because several studies have reported that the increased risk of cesarean delivery associated with obesity was greater among women without complications (4,10–13), we calculated a separate pooled estimate using studies that restricted their population to women without complications or studies that stratified their results by women with and without complications. Although the definition of complications varied among studies, we considered studies to account for complications if they excluded women with gestational diabetes or pregnancy-induced hypertension and/or one or more of the following: fetal distress, excessive bleeding, placenta previa, prolonged labour, cephalopelvic disproportion, excessive bleeding, or other chronic conditions.

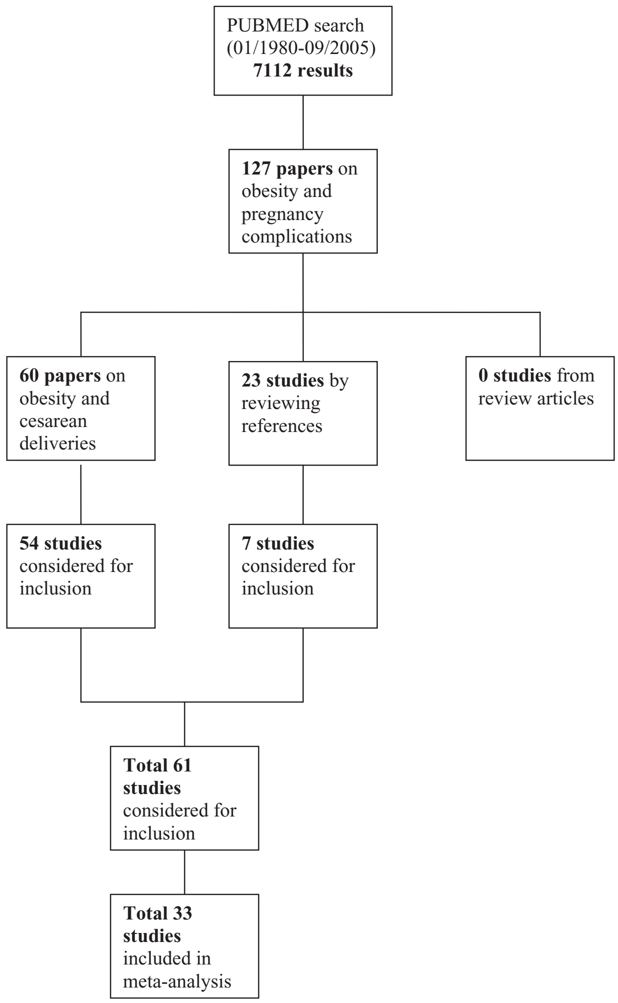

Figure 1 Meta-analysis selection process flow-chart.

Results

Figure 1 shows the flow diagram of the literature search results. The PubMed search identified 7112 studies; 127 abstracts reported a finding on the relationship between maternal obesity and pregnancy complications from a case–control or cohort study and these articles were retrieved for detailed examination. Of the retrieved articles, 60 studies mentioned cesarean delivery as an outcome. Of these 60 studies, we excluded three that focused on VBAC delivery and two that were older analyses of the same study population of an included study. Because only one case–control study selected, we also excluded that study, leaving a total of 54 studies from the PubMed search to be screened for inclusion. After reviewing the reference lists of the 127 studies retrieved, we identified another seven studies for possible inclusion. No additional studies were identified from our examination of recent review article reference lists. Of the total 61 studies screened for final inclusion in the meta-analysis, 28 were excluded because the BMI or weight measure did not reflect pre-pregnancy status ($n = 9$), there was no normal weight comparison group or overweight and obese groups were combined ($n = 11$), or data were not presented in a way to allow calculation of crude ORs ($n = 8$). Five studies were translated to English (four from French, one from Danish).

Therefore, a total of 33 studies were included in the meta-analysis; of these, 24, 29 and seven presented data for overweight, obese and severely obese pregnant women, respectively, compared with normal weight pregnant women (3,4,6,10–39). Sixteen studies were conducted in the United States; the remainder were from Sweden, France, Denmark, Israel, Canada, the United Kingdom, Poland and United Arab Emirates (Table 1). Eleven of the studies were prospectively designed. The rates of cesarean delivery among normal weight women varied notably among the studies, ranging from 2.1% to 40.3%. Four studies excluded women with pre-existing diabetes mellitus (DM) or gestational diabetes mellitus (GDM) and two studies excluded women with DM only. Five studies adjusted for both DM and GDM and two adjusted for GDM only in their multivariate analyses.

Based on our meta-analysis, the odds of a cesarean delivery were 1.46 (95% CI: 1.34–1.60), 2.05 (95% CI: 1.86–2.27) and 2.89 (95% CI: 2.28–3.79) higher, respectively, among overweight, obese and severely obese compared with normal weight pregnant women (Table 2). The ORs among studies showed little variability despite certain notable study differences, and none of the covariates in the meta-regression analysis were significant [study year (<2000, 2000–2003, 2004–2005); study design (prospective, retrospective); geographical location (US, non-US); parity (nulliparous, multiparous); rate of cesarean delivery in normal weight women in each study].

In addition, because a number of studies have reported that the increased risk of cesarean delivery associated with obesity was greater among women without complications or defined as 'low risk', we did a separate meta-analysis of those studies that included low-risk women only or that presented findings stratified by risk. Among those studies ($n = 12$), the odds of a cesarean delivery were 1.41 (95% CI: 1.17–1.69) and 1.75 (95% CI: 1.41–2.23) higher, respectively, among overweight and obese women without complications compared with normal weight pregnant women without complications (only one study compared severely obese women). Although the odds of a cesarean delivery increased and became significant for overweight women as compared with all women, the odds decreased for obese women without complications or of low risk; neither of these changes in estimates from the results for all women was notable.

Table 2 Pooled estimates of the effect of pre-pregnancy weight on the odds of cesarean delivery (bayes analysis)

Comparison groups	Number of studies	OR	95% CI
Overweight vs. normal	23	1.46	1.34–1.60
Obese vs. normal	29	2.05	1.86–2.27
Severely obese vs. normal	7	2.89	2.28–3.79

Discussion

Based on meta-analysis of the literature, we estimate that the risk of a cesarean delivery is about two and three times higher, respectively, among obese and severely obese compared with normal weight pregnant women. Because every year nearly 4 000 000 women give birth in the United States, each 1% increment in this population that is obese represents 40 000 women. If normal weight women have a 20% risk of cesarean delivery (4), and assuming that obese women have twice that risk, each 1% decrease in the fraction of birthing women who are obese would translate into

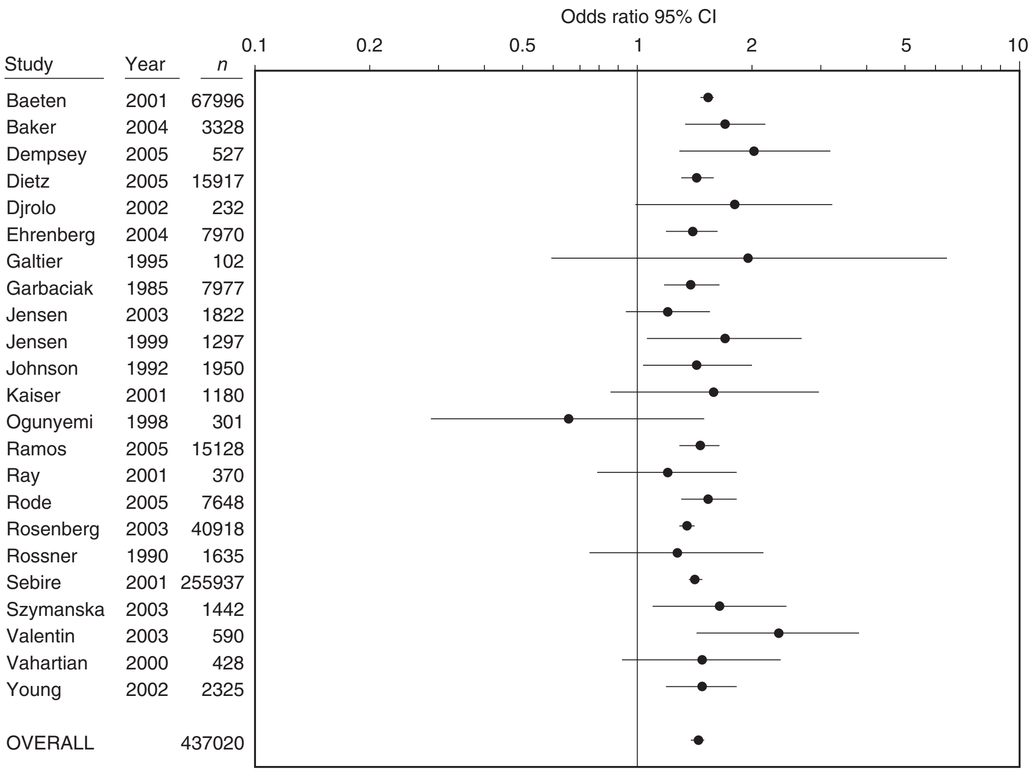

Figure 2 Association of cesarean delivery with overweight versus normal maternal BMI.

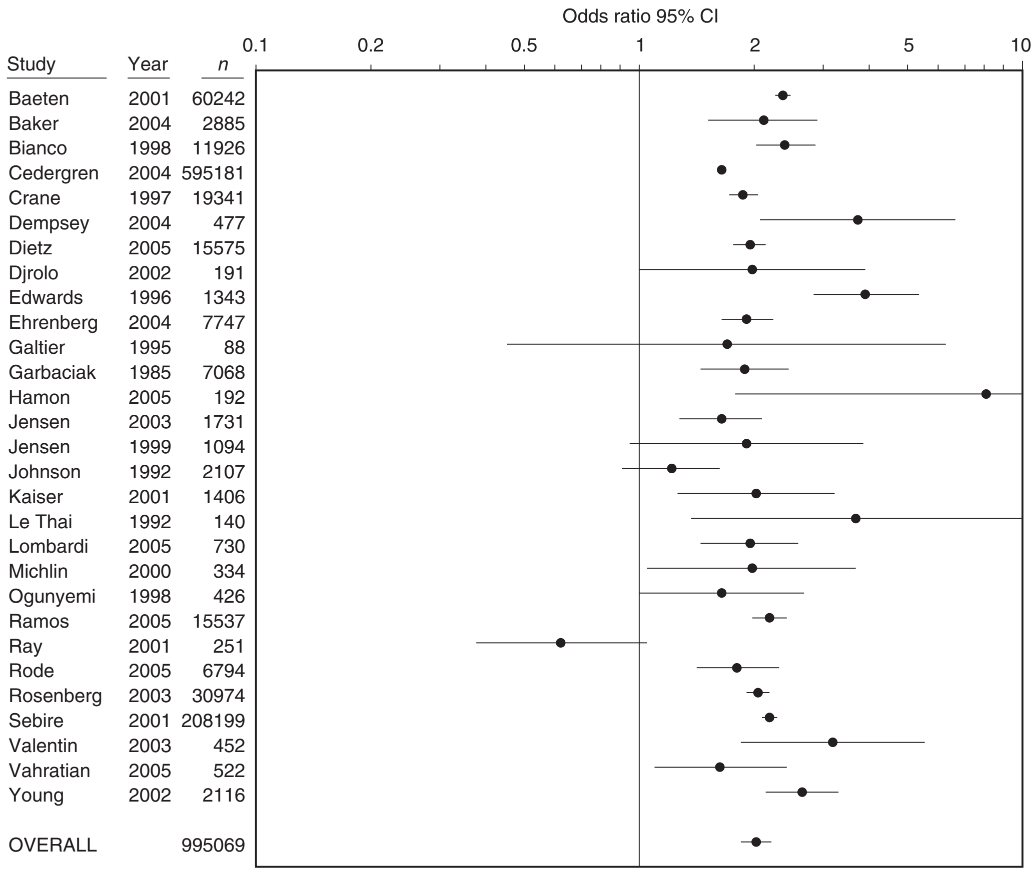

Figure 3 Association of cesarean delivery with obese versus normal maternal BMI.

16 000 fewer cesarean deliveries per year. Because obesity is a modifiable risk with a substantial prevalence in the United States (2) and other developed countries, the impact of reducing that exposure can be considerable (40–42).

The biological pathway through which obesity affects the labour process is not well understood (4,43). Some have suggested that obesity increases maternal pelvic soft tissue which narrows the diameters of the birth canal and increases the risks associated with dystocia (6,8,12,39), a macrosomic infant, or cephalopelvic disproportion (44,45); others have suggested that the increased risk of cesarean deliveries could be related to differences in labour progression among obese women or their response to oxytocin administration (46). Maternal obesity also has been associated with higher rates of intrapartum meconium staining or cord accidents, conditions that can affect decisions about the mode of delivery (10,35,47). Obesity can affect the risk of a cesarean delivery by increasing the risk of other complications of pregnancy, particularly gestational diabetes (48–50). However, as has been suggested by others (12,31,51–57) and is supported by our analysis, the consistently increased risk of cesarean delivery among obese women with (31,58) or without gestational diabetes (11–13,16,26,59) or after controlling for this conditions in the analyses (4,6,20,21,25,30,35) implies that obesity increases the risk of cesarean delivery, in addition to, and independent of, the effects of gestational diabetes.

In addition, the effect of obesity on cesarean delivery risk was strikingly consistent across race/ethnicity groups and geographical locations, by parity status, and in studies that included either emergency or elective cesarean deliveries only. And although a number of studies have reported that the increased risk of cesarean delivery associated with obesity was greater among women without complications (4,10–13), we did not find any notable difference in the risk of cesarean delivery among these women. The independent and consistent finding suggests that overweight and obesity, *per se*, during pregnancy should be considered a risk for cesarean delivery regardless of other complications of obesity (11,13,43). Moreover, intensified monitoring may be needed for this group because obese women are much more likely to experience infections and other complications from cesarean delivery than are non-obese women (60–63), with longer hospital stays and rehospitalization and higher costs (64–66). Given these increased risks, future research is needed to better understand the mechanisms by

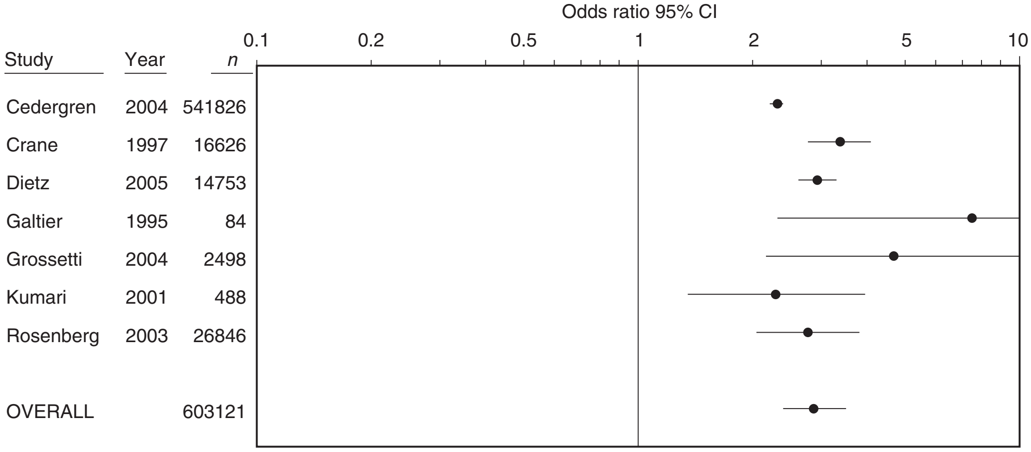

Figure 4 Association of cesarean delivery with severely obese versus normal maternal BMI.

which maternal obesity causes cesarean deliveries as well as the potential impact of weight loss before pregnancy.

Several sources of error should be considered. First, the studies included in this meta-analysis used varying weight and BMI categories for normal, overweight, obese and severely obese women. Although the ranges for each category were fairly consistent, the pooled estimate does not exactly reflect the same comparison for all studies. In addition, because of the different weight/BMI categories, there is likely some misclassification of the exposure; if significant, the findings would be biased or cause significant heterogeneity in the meta-analysis model. However, the fairly consistent results among the studies suggest this had a minimal effect on our finding (Figs 2–4).

Second, because not all studies presented adjusted odds and adjustment factors varied among those that did, we only used crude study estimates in our meta-analysis. If there were strong effects from confounding factors(e.g. maternal age is associated with both increased body weight and risk of cesarean delivery), the estimates included in the meta-analysis might be biased. However, when we did a separate meta-analysis pooling studies that provided adjusted ORs comparing obese and normal weight pregnant women (the number of studies with adjusted odds for the other BMI categories was inadequate for stable estimates), there was very little change in the summary OR ($n = 9$; pooled adjusted OR = 2.02; 95% CI = 1.71–2.41) suggesting minimal bias. Finally, our findings may be biased because published studies do not represent all studies ever performed on a particular subject and statistically significant results are more likely to be submitted and published than non-significant and null results (67). If study publication bias were strong, we would overestimate the risk of cesarean delivery with increasing BMI.

Our findings suggest that an additional health consequence of obesity is an increased risk of cesarean delivery and given the rapid increase in obesity prevalence in the United States, even a modest effect of obesity on cesarean delivery rates could have substantial population impact.

Conflict of Interest Statement

No conflict of interest was declared.

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