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

S. Y. Chu, S. Y. Kim, C. H. Schmid, P. M. Dietz, W. M. Callaghan, J. Lau and K. M. Curtis

1Division of Reproductive Health, Centers for Disease Control and Prevention, Mailstop K23, 1600 Clifton Road, Atlanta, GA, USA, 2Institute for Clinical Research and Health Policy Studies, Tufts-New England Medical Center, 750 Washington St., Boston, MA, USA.

Received 5 March 2007; revised 1 May 2007; accepted 24 May 2007

Correspondence: SY Chu, Centers for Disease Control and Prevention, 1600 Clifton Road, N.E., Mailstop K-23, Atlanta, GA 30333, USA.
E-mail: syc1@cdc.gov

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.

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...
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 focused only 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 $2 \times 2$ 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 hyper-parameters, 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 $(1.0, 0.1)$
| Citation | Country study period | Type and source of cohort | Cohort size | CD rate normal weight women (%) | Exclusion criteria | BMI/weight categories |
|----------|----------------------|---------------------------|-------------|---------------------------------|-------------------|----------------------|
| Baeten et al. (14) | United States 1992–1996 | Prospective cohort from state birth certificate records | 96,801 | 16.6 | No | Normal 20–24.9, ≥30, NA |
| Baker et al. (15) | Denmark (years not given) | Prospective cohort from national birth registry | 3,768 | 9.8 | Yes | 18.5–24.9, ≥30, NA |
| Bianco et al. (16) | United States 1988–1995 | Retrospective cohort from a medical centre’s perinatal database | 11,926 | 15.9 | No | Normal 19–27, ≥35, NA |
| Cedergren et al. (17) | Sweden 1992–2001 | Prospective cohort from national birth registry | 621,221 | 10.9 | No | Normal 19.8–26, ≥35, NA |
| Crane et al. (6) | United States 1994–1995 | Retrospective cohort from a regional perinatal data system | 16,391 | 20.2 | No | Normal 19.8–26, ≥35, NA |
| Dempsey et al. (18) | United States 1996–2000 | Prospective cohort from prenatal care clinics | 738 | 23.1 | Yes | Normal 19.8–26, ≥35, NA |
| Dietz et al. (4) | United States 1998–2000 | Retrospective cohort based on a multi-state surveillance system from birth certificates | 24,423 | 20.1 | No (adj) | Normal 19.8–26, ≥35, NA |
| Djärolo, 2002 | France 1999 | Retrospective cohort from obstetric clinics | 323 | 21.1 | No | Normal 19.8–26, ≥35, NA |
| Edwards et al. (20) | United States 1977–1993 | Retrospective cohort from medical centre | 1,343 | 9.1 | No (adj) | Normal 19.8–26, ≥35, NA |
| Ehrenberg et al. (21) | United States 1997–2001 | Retrospective cohort from tertiary centre perinatal database | 12,303 | 7.7 | No (adj) | Normal 19.8–26, ≥35, NA |
| Galtier-Dereure et al. (22) | France 1990–1993 | Retrospective cohort from obstetrics department | 166 | 9.3 | Yes | Normal 8–24.9, ≥30, NA |
| Garbaciak et al. (10) | United States 1982 | Prospective cohort from a perinatal network of maternal and infant medical records | 9,667 | 10.4 | No | Normal 85–120%, ≥150%, NA |
| Grossetti et al. (23) | France 2002–2003 | Retrospective cohort from maternity wards | 2,496 | 15.4 | No | Normal 20–25, ≥40, NA |
| Hamon et al. (13) | France 2002 | Retrospective cohort from obstetric clinics | 192 | 2.1 | Yes | Normal ≤25, ≥30, NA |
| Jensen et al. (24) | Denmark 1993–1995 | Retrospective cohort from a hospital database | 1,699 | 6.0 | No | Normal 20–24.9, ≥30, NA |
| Jensen et al. (11) | Denmark 1992–1996 | Prospective cohort from university hospital clinics | 2,459 | 14.7 | Yes | Normal 18.5–24.9, ≥30, NA |
| Citation                | Country study period | Type and source of cohort                      | Cohort size | CD rate normal weight women (%) | Exclusion criteria | BMI/weight categories |
|------------------------|----------------------|------------------------------------------------|-------------|---------------------------------|--------------------|-----------------------|
| 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              | 100–149 lbs           | 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. | 32 395      | 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 1996–2002 | 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 Woodwardsee (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.

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.

### 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

### 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 |

### Figure 2

Association of cesarean delivery with overweight 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 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 among obese women or their response to oxytocin administration (46).

Figure 3 Association of cesarean delivery with 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.

**References**

1. Menacker F. Trends in cesarean rates for first births and repeat cesarean rates for low-risk women: United States, 1990–2003. *Natl Vital Stat Rep* 2005; 54: 1–8.
2. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 2006; 295: 1549–1555.
3. Lombardi DG, Barton JR, O'Brien JM, Istwan NK, Sibai BM. Does an obese prepregnancy body mass index influence outcome in pregnancies complicated by mild gestational hypertension remote from term? *Am J Obstet Gynecol* 2005; 192: 1472–1474.
4. Dietz PM, Callaghan WM, Morrow B, Cogswell ME. Population-based assessment of the risk of primary cesarean delivery due to excess prepregnancy weight among nulliparous women delivering term infants. *Matern Child Health J* 2005; 9: 237–244.
5. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, Moher D, Becker BJ, Sipe TA, Thacker SB. Meta-analysis of observational studies in epidemiology: a proposal for reporting. *Meta-analysis of Observational Studies in Epidemiology (MOOSE) group. JAMA* 2000; 283: 2008–2012.
6. Crane SS, Wojtowycz MA, Dye TD, Aubry RH, Artal R. Association between pre-pregnancy obesity and the risk of cesarean delivery. *Obstet Gynecol* 1995; 89: 213–216.
7. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986; 7: 177–188.
8. Schmid CH, Stark PC, Berlin JA, Landais P, Lau J. Meta-regression detected associations between heterogeneous treatment effects and study-level, but not patient-level, factors. *J Clin Epidemiol* 2004; 57: 683–697.
9. Gelman A, Carlin JB, Stern HS, Rubin DB. *Bayesian Data Analysis*, 2nd edn. New York: Chapman & Hall, 1996, 294–299.
10. Garbaciak JA Jr, Richter M, Miller S, Barton JJ. Maternal weight and pregnancy complications. *Am J Obstet Gynecol* 1985; 152: 238–243.

11. Jensen DM, Damm P, Sorensen B, Molsted-Pedersen L, Westergaard JG, Ovesen P, Beck-Nielsen H. Pregnancy outcome and prepregnancy body mass index in 2459 glucose-tolerant Danish women. *Am J Obstet Gynecol* 2003; 189: 239–244.

12. Kaiser PS, Kirby RS. Obesity as a risk factor for cesarean in a low-risk population. *Obstet Gynecol* 2001; 97: 39–43.

13. Hamon C, Fanello S, Catala L, Parot E. [Maternal obesity: effects on labor and delivery. ‘Excluding other diseases that might modify obstetrical management’.] *J Gynecol Obstet Biol Reprod (Paris)* 2005; 34: 109–114.

14. Baeten JM, Bukusi EA, Lambe M. Pregnancy complications and outcomes among overweight and obese nulliparous women. *Am J Public Health* 2001; 91: 436–440.

15. Baker JL, Michelsen KE, Rasmussen KM, Sorensen TI. Maternal prepregnant body mass index, duration of breastfeeding, and timing of complementary food introduction are associated with infant weight gain. *Am J Clin Nutr* 2004; 80: 1579–1588.

16. Bianco AT, Smilen SW, Davis Y, Lopez S, Lapinski R, Lockwood CJ. Pregnancy outcome and weight gain recommendations for the morbidly obese woman. *Obstet Gynecol* 1998; 91: 97–102.

17. Cedergren ML. Maternal morbid obesity and the risk of adverse pregnancy outcome. *Obstet Gynecol* 2004; 103: 219–224.

18. 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: 179–185.

19. Djrolo F, Mkgngho OA, De SJ, Takpara I, Santos P, Alhounou E. [Influence of maternal weight on pregnancy outcome in Cotonou (Benin).] *J Gynecol Obstet Biol Reprod (Paris)* 2002; 31: 243–247.

20. Edwards LE, Hellerstedt WL, Alton IR, Story M, Himes JH. Maternal prepregnant body mass index and neonatal mortality for primary cesarean and vaginal births to women with ‘no indicated risk’, United States, 1998–2001 birth survey on maternal and perinatal health in Latin America. *Lancet* 2006; 367: 1819–1829.

21. Galitier-Dereure F, Montpeyroux F, Boulot P, Bringer J, Jaffiol C. Weight excess before pregnancy: complications and cost. *Int J Obes Relat Metab Disord* 1995; 19: 443–448.

22. Grossetti E, Beucher G, Regasse A, Lamendour N, Herlicoviez M, Dreyfus F. Obstetrical complications of morbidity obesity. *J Gynecol Obstet Biol Reprod (Paris)* 2004; 33: 739–744.

23. Jensen H, Agger AO, Rasmussen KL. The influence of prepregnancy body mass index on labor complications. *Acta Obstet Gynecol Scand* 1999; 78: 799–802.

24. Johnson JW, Longmate JA, Frenzten B. Excessive maternal weight and pregnancy outcome. *Am J Obstet Gynecol* 1992; 167: 353–370.

25. Kumari AS. Pregnancy outcome in women with morbid obesity. *Int J Gynaecol Obstet* 2001; 73: 101–107.

26. Le TN, Lefebvre G, Stella V, Vauthier D, Sfiggia D, Goulou V, Darbois Y. Pregnancy and obesity. A case control study of 140 cases. *J Gynecol Obstet Biol Reprod (Paris)* 1992; 21: 563–567.

27. Michlin R, Oettinger M, Odeh M, Khoury S, Ophir E, Barak M, Wolfson M, Strulov A. Maternal obesity and pregnancy outcome. *Isr Med Assoc J* 2000; 2: 10–13.

28. Oggunyemi 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: 190–193.

30. Ramos GA, Caughey AB. The interrelationship between ethnicity and obesity on obstetric outcomes. *Am J Obstet Gynecol* 2005; 193: 1089–1093.

31. Ray JG, Vermeulen MJ, Shapiro JL, Keshohle AB. Maternal and neonatal outcomes in pregestational and gestational diabetes mellitus, and the influence of maternal obesity and weight gain: the DEPOSIT study. Diabetes Endocrine Pregnancy Outcome Study in Toronto. *QJM* 2001; 94: 347–356.

32. Rode I, Nilas L, Wojdemann K, Tabor A. Obesity-related complications in Danish single cephalic term pregnancies. *Obstet Gynecol* 2005; 105: 537–542.

33. Rosenberg TJ, Garbers S, Chavkin W, Chiasson MA. Prepregnancy weight and adverse perinatal outcomes in an ethnically diverse population. *Obstet Gynecol* 2003; 102: 1022–1027.

34. Rossner S, Ohlin A. Maternal body weight and relation to birth weight. *Acta Obstet Gynecol Scand* 1990; 69: 475–478.

35. Sebire NJ, Jolly M, Harris JP, Wadsworth J, Joffe M, Beard RW, Regan I, Robinson S. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. *Int J Obstet Relat Metab Disord* 2001; 25: 1175–1182.

36. Szymanska M, Suchonska B, Wielgos M, Bomba-Opion D, Marianowski L. Pregnancy and labor in obese women. *Ginekol Pol* 2003; 74: 446–450.

37. Vahriyan A, Siega-Riz AM, Savitz DA, Zhang J. Maternal pre-pregnancy overweight and obesity and the risk of cesarean delivery in nulliparous women. *Am Epidemiol* 2005; 15: 467–474.

38. Valentin TD, Sorensen JA, Andresen EE. Obese pregnant women have complicated deliveries. *Ugeskr Laeger* 2003; 165: 1027–1030.

39. 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: 312–318.

40. Vilar J, Valladares E, Wojdyla D, Zavaleta N, Carroli G, Velasco A, Shah A, Campodonico L, Bataglia V, Faundes A, Langer A, Narvaez A, Donner A, Romero M, Reynoso S, Simonia de Padua K, Giordano D, Kubickas M, Acosta A. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. *Lancet* 2006; 367: 1819–1829.

41. Macdorman MF, Declercq E, Menacker F, Malloy MH. Infant and neonatal mortality for primary cesarean and vaginal births to women with ‘no indicated risk’, United States, 1998–2001 birth cohorts. *Birth* 2006; 33: 175–182.

42. Deneux-Tharaux C, Carmona E, Bouvier-Colle MH, Breart G. Postpartum maternal mortality and cesarean delivery. *Obstet Gynecol* 2006; 104: 541–548.

43. ACOG Committee. Opinion number 315, September 2005. *Obstet Gynecol* 2005; 106: 671–675.

44. Isaacs JD, Magann EF, Martin RW, Chauhan SP, Morrison JC. Obstetric challenges of massive obesity complicating pregnancy. *J Perinatol* 1994; 14: 10–14.

45. Witter FR, Caulfield LE, Stoltzfus RJ. Influence of maternal anthropometric status and birth weight on the risk of cesarean delivery. *Obstet Gynecol* 1995; 85: 947–951.

46. Vahratian A, Zhang J, Troendle JF, Savitz DA, Siega-Riz AM. Maternal prepregnancy overweight and obesity and the pattern of labor progression in term nulliparous women. *Obstet Gynecol* 2004; 104: 943–951.

47. Cnattingius R, Cnattingius S, Notzon FC. Obstacles to reducing cesarean rates in a low CESAREAN SETTING: THE EFFECT OF MATERNAL AGE, HEIGHT, AND WEIGHT. *Obstet Gynecol* 1998; 92: 501–506.

48. Yang X, Hsu-Hage B, Zhang H, Zhang C, Zhang Y, Zhang C. Women with impaired glucose tolerance during pregnancy have...
significantly poor pregnancy outcomes. *Diabetes Care* 2002; 25: 1619–1624.

49. Casey BM, Lucas MJ, McIntire DD, Leveno KJ. Pregnancy outcomes in women with gestational diabetes compared with the general obstetric population. *Obstet Gynecol* 1997; 90: 869–873.

50. Greene MF, Solomon CG. Gestational diabetes mellitus – time to treat. *N Engl J Med* 2005; 352: 2544–2546.

51. Sermer M, Naylor CD, Farine D, Kenshole AB, Ritchie JW, Gare DJ, Cohen HR, McArthur K, Holzapfel S, Biringer A. The Toronto Tri-Hospital Gestational Diabetes Project. A preliminary review. *Diabetes Care* 1998; 21: B33–B42.

52. Weiss JL, Malone FD, Emig D, Ball RH, Nyberg DA, Comstock CH, Saade G, Eddleman K, Carter SM, Craigo SD, Carr SR, D’Alton ME. Obesity, obstetric complications and cesarean delivery rate – a population-based screening study. *Am J Obstet Gynecol* 2004; 190: 1091–1097.

53. Linne Y. Effects of obesity on women’s reproduction and complications during pregnancy. *Obes Rev* 2004; 5: 137–143.

54. Bo S, Menato G, Signorile A, Bardelli C, Lezo A, Gallo ML, Gambino R, Cassader M, Massobrio M, Pagano G. Obesity or diabetes: what is worse for the mother and for the baby? *Diabetes Metab* 2003; 29: 175–178.

55. Rosenberg TJ, Garbers S, Lipkind H, Chiasson MA. Maternal obesity and diabetes as risk factors for adverse pregnancy outcomes: differences among 4 racial/ethnic groups. *Am J Public Health* 2005; 95: 1545–1551.

56. Ricart W, Lopez J, Mozaz J, Pericot A, Sancho MA, Gonzalez N, Balsells M, Luna R, Cortazar A, Navarro P, Ramirez O, Flandez B, Pallardo LF, Hernandez-Mijas A, Ampudia J, Fernandez-Real JM, Corcoy R. Body mass index has a greater impact on pregnancy outcomes than gestational hyperglycaemia. *Diabetologia* 2005; 48: 1736–1742.

57. Villamor E, Cnattingius S. Interpregnancy weight change and risk of adverse pregnancy outcomes: a population-based study. *Lancet* 2006; 368: 1164–1170.

58. Philipson EH, Kalhan SC, Edelberg SC, Williams TG. Maternal obesity as a risk factor in gestational diabetes. *Am J Perinatol* 1985; 2: 268–270.

59. Usha Kiran TS, Hemmadi S, Bethel J, Evans J. Outcome of pregnancy in a woman with an increased body mass index. *BJOG* 2005; 112: 768–772.

60. Burrows LJ, Meyn LA, Weber AM. Maternal morbidity associated with vaginal vs. cesarean delivery. *Obstet Gynecol* 2004; 103: 907–912.

61. Hood DD, Dewan DM. Anesthetic and obstetric outcome in morbidly obese parturients. *Anesthesiology* 1993; 79: 1210–1218.

62. Myles TD, Gooch J, Santolaya J. Obesity as an independent risk factor for infectious morbidity in patients who undergo cesarean delivery. *Obstet Gynecol* 2002; 100: 959–964.

63. Perlow JH, Morgan MA. Massive maternal obesity and peripartum cesarean morbidity. *Am J Obstet Gynecol* 1994; 170: 560–565.

64. Chauhan SP, Magann EF, Carroll CS, Barrilleaux PS, Scarso JA, Martin JN Jr. Mode of delivery for the morbidly obese with prior cesarean delivery: vaginal versus repeat cesarean section. *Am J Obstet Gynecol* 2001; 185: 349–354.

65. Lydon-Rochelle M, Holt VL, Martin DP, Easterling TR. Association between method of delivery and maternal rehospitalization. *JAMA* 2000; 283: 2411–2416.

66. Webb DA, Robbins JM. Mode of delivery and risk of postpartum rehospitalization. *JAMA* 2003; 289: 46–47.

67. Petitti D. Meta-analysis, Decision Analysis, and Cost-Effectiveness Analysis. Oxford University Press: New York, 2000.