Maternal Prepregnancy Overweight and Obesity and the Pattern of Labor Progression in Term Nulliparous Women

Anjel Vahratian, PhD, MPH, Jun Zhang, PhD, MD, James F. Troendle, PhD, David A. Savitz, PhD, and Anna Maria Siega-Riz, PhD

OBJECTIVE: **To examine the effect of maternal overweight and obesity on labor progression.**

METHODS: **We analyzed data from 612 nulliparous women with a term pregnancy that participated in the Pregnancy, Infection, and Nutrition Study from 1995 to 2002. The median duration of labor by each centimeter of cervical dilation was computed for normal-weight (body mass index [BMI] 19.8–26.0 kg/m^2), overweight (BMI 26.1–29.0 kg/m^2), and obese (BMI > 29.0 kg/m^2) women and used as a measurement of labor progression.**

RESULTS: **After adjusting for maternal height, labor induction, membrane rupture, oxytocin use, epidural analgesia, net maternal weight gain, and fetal size, the median duration of labor from 4 to 10 cm was significantly longer for both overweight and obese women, compared with normal-weight women (7.5, 7.9, and 6.2 hours, respectively). For overweight women, the prolongation was concentrated around 4–6 cm, whereas for obese women, their labor was significantly slower before 7 cm.**

CONCLUSION: **Labor progression in overweight and obese women was significantly slower than that of normal-weight women before 6 cm of cervical dilation. Given that nearly one half of women of childbearing age are either overweight or obese, it is critical to consider differences in labor progression by maternal prepregnancy BMI before additional interventions are performed. (Obstet Gynecol 2004;104:943–51. © 2004 by The American College of Obstetricians and Gynecologists.)**

From the Departments of Maternal and Child Health and Epidemiology, School of Public Health; the Department of Nutrition, School of Medicine and School of Public Health; and the Carolina Population Center, The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina; and the Division of Epidemiology, Statistics, and Prevention Research, National Institute of Child Health and Human Development, National Institutes of Health, U.S. Department of Health and Human Services, Bethesda, Maryland.

The authors thank the many investigators and staff members who worked in a joint effort on the Pregnancy, Infection, and Nutrition Study.

The Pregnancy, Infection, and Nutrition Study is supported by the National Institute of Child Health and Human Development, National Institutes of Health (grants HD28684, HD05798, and HD37584), The Association of Schools of Public Health/Centers for Disease Control and Prevention (cooperative agreement S455-16/17, S0807-18/20), and the Wake Area Health Education Center in Raleigh, North Carolina. The study is also supported in part by a grant (RR00046) from the General Clinical Research Centers program of the Division of Research Resources, National Institutes of Health. Dr. Vahratian was supported in part by a National Institute of Child Health and Human Development Intramural Research Training Award.

Presented in part at the Twenty-Fourth Annual Meeting of the Society for Maternal-Fetal Medicine, New Orleans, Louisiana, February 2–7, 2004, and the Seventeenth Annual Meeting of the Society for Pediatric and Perinatal Epidemiologic Research, Salt Lake City, Utah, June 14–15, 2004.

The prevalence of overweight and obesity is increasing among women of childbearing age. An estimated 22% of nonpregnant women 18–49 years of age in the United States are considered overweight (body mass index [BMI] 25–29.9 kg/m^2) and an additional 22% are classified as obese (BMI $>$ 29.9 kg/m^2).[1] Observational studies show that obese women have up to a 2-fold increased risk for a cesarean delivery compared with normal-weight women.[2–9] However, it is unclear what factors may contribute to this elevated risk, because scientific evidence on the effect of maternal prepregnancy weight status on labor progression is still limited.[8,10] Does the course of labor tend to differ for overweight and obese women, compared with that of normal-weight women? The purpose of this study was to examine the effect of maternal overweight and obesity on the pattern of labor progression in nulliparous women with a singleton, term pregnancy.

MATERIALS AND METHODS

Women in this study were participants in the Pregnancy, Infection, and Nutrition Study, an ongoing, prospective cohort study designed to examine the determinants of preterm birth.[11] Between August 1995 and June 2000, women at 24–29 weeks of gestation were recruited into the study from the following prenatal care clinics in central North Carolina: the University of North Caro-

Published by Lippincott Williams & Wilkins. 0029-7844/04/$30.00 doi:10.1097/01.AOG.0000142713.53197.91

lina Hospital Residents Clinic, the University of North Carolina Hospital Obstetrics Group, the Wake County Department of Human Services Clinic, and the affiliated High-Risk Clinic at Wake Medical Center Area Health Education Center. Starting in January 2001, women at less than 20 weeks of gestation continued to be recruited into the study from the University of North Carolina prenatal care clinics only.

Women were eligible to participate in the Pregnancy, Infection, and Nutrition Study if they met the following inclusion criteria: maternal age of at least 16 years at the time of recruitment, singleton pregnancy, the ability to speak English, telephone access, a prenatal visit before study enrollment, and a plan to be delivered at either University of North Carolina Hospitals or Wake Medical Center. Telephone interviews and self-administered questionnaires collected data regarding sociodemographic characteristics, current pregnancy information, reproductive and medical histories, and health behaviors. Delivery logs were subsequently examined to determine birth-outcome information on all participants, and medical abstractions were performed to collect information on maternal health complications during pregnancy and maternal weight at each prenatal visit. All participants gave informed consent at the time of recruitment, and the institutional review boards of the University of North Carolina School of Medicine and Wake Medical Center approved the study.

Between August 1995 and March 2002, the Pregnancy, Infection, and Nutrition Study recruited 3,625 women. Maternal prepregnancy BMI, our exposure of interest, was computed based on the following Institute of Medicine weight-for-height categories: normal weight (BMI 19.8–26.0 kg/m^2), overweight (BMI 26.1–29.0 kg/m^2), and obese (BMI $>$ 29.0 kg/m^2).[12] Participants were eligible for this analysis if they met the following additional inclusion criteria: nulliparous, a maternal prepregnancy BMI of 19.8 kg/m^2 or higher, and a term delivery (N = 1,060; n = 670 [normal], n = 135 [overweight], n = 255 [obese]). Because limited information was originally collected on intrapartum factors, medical record abstractions were sought for 100% of the eligible overweight and obese women and a random sample of 50% of the eligible normal-weight women (N = 710; n = 345 [normal], n = 126 [overweight], and n = 239 [obese]). Intrapartum data, including the results from vaginal examination measurements, were entered directly into a custom-designed laptop medical record abstraction system in Microsoft Access to minimize errors in data entry. During medical abstractions, term status was found to have been misclassified in 3 women (1 normal and 2 overweight), whereas nulliparity was misclassified in 10 women (4 normal, 2 overweight, and 4 obese). Patient charts with complete information on the index pregnancy could not be located for 56 women (31 normal, 3 overweight, and 22 obese), and 29 women were admitted for an elective cesarean delivery without a trial of labor (12 normal, 4 overweight, 13 obese). Thus, our final sample consisted of 612 women (297 normal, 115 overweight, and 200 obese). The institutional review board at the University of North Carolina School of Public Health approved this study.

Prepregnancy weight was obtained from medical records and based on maternal self-report. If this information was missing or considered implausible by study investigators, then it was obtained from a self-administered screening questionnaire at the time of recruitment. Measured weight at first prenatal visit was used in lieu of the self-reported measure only when both were missing or implausible and the first visit was at less than 16 weeks of gestation. In such cases, the first measured weight between 1 and 15 weeks of gestation was used, with a correction for the week of first weight measurement.[13] If the first weight measurement was after 15 weeks of gestation, a prepregnancy weight could not be imputed. Self-reported prepregnancy weights are known to correlate well with measured weights,[14–16] and every effort was made by Pregnancy, Infection, and Nutrition Study investigators to verify self-reported prepregnancy weights with measured weight at first prenatal visit. Maternal height was measured and recorded at the first prenatal visit or obtained later during medical record abstraction.

The median duration of labor by each centimeter of cervical dilation was computed based on data from serial vaginal exams and used as a measurement of labor progression, our outcome of interest. Total maternal weight gain during pregnancy was calculated by subtracting the weight at the first prenatal visit from the weight at the last prenatal visit. Adequacy of weight gain was determined based on Institute of Medicine weight-for-height classifications[12] and for bivariate analyses was dichotomized as either inadequate/adequate (less than or within the recommended range) or excessive (greater than the upper cutoff of recommendations). For the purposes of multivariable analysis, a continuous measurement of net weight gain (total weight gain minus infant birth weight) was included in the model in addition to infant birth weight to account for the effect of maternal and fetal weight separately. Maternal age is defined as age in completed years at the time of recruitment. Prenatal care type refers to whether the patient received prenatal care through the university's obstetrical group (private), the university's resident clinics (public), the Wake County Department of Human Services Clinic (public), or the high-risk clinic at the Wake Medical Center Area Health Education Center.

To assess the effect of maternal prepregnancy weight status on labor progression, we first compared various baseline characteristics of the subjects, stratified by maternal prepregnancy BMI. For continuous variables with a normal distribution, the mean and standard deviation values were calculated and *t* tests were performed. For continuous variables with a skewed distribution, the median and the values at the 10th and 90th percentiles were indicated and the Wilcoxon rank-sum test was performed. For categorical data, percentages were calculated and the χ^2 test was used. Variables that were significantly different between the two groups and associated with the duration of labor were selected as potential confounders for multivariable analyses.

Next, we used survival analysis to quantify the duration of the first stage of labor and specifically, the median time elapsed for women to proceed from one centimeter of cervical dilation to the next for each BMI group. Because continuous monitoring of cervical dilation was not performed and women were admitted into labor at different degrees of cervical dilation, it is impossible to know exactly when an individual first reaches a given level of dilation. However by considering these times as censored, the median duration of labor can be estimated using the interval-censored regression method.[17]

For each interval of cervical dilation (eg, from 3 to 4 cm), a lower and upper possible time range was computed from each labor log. Thus, each individual contributed an interval-censored value at a given level of dilation. Interval-censoring can be defined as "when the time of event occurrence is known to be somewhere between times a and b, but we don't know exactly when."[18] For example, if we knew that an individual labor took at least 2 hours to progress from 4 to 5 cm but no longer than 5 hours, the interval [2, 5] would be used to model the underlying distribution of the duration of labor from 4 to 5 cm. It is well established that the duration of labor has a skewed distribution leaning toward the left (ie, some labors produce a long right tail of the distribution). This distribution generally fits a log normal distribution. Thus, a natural assumption for the data comprising the time interval is that they are log normally distributed, which was consistent with our data.

We fitted a model with a log normal distribution and interval-censored time-to-event data to assess the median duration of time elapsed in hours for each centimeter of cervical dilation during labor using the LIFEREG procedure in SAS (SAS Institute, Cary, NC). Adjustment was made for baseline characteristics that were associated with prepregnancy BMI and the duration of labor, based on a *P* value of less than .20. These covariates included net weight gain, labor induction, oxytocin use, and fetal size. Maternal height, the timing and use of epidural analgesia, and the timing of membrane rupture were included in the final adjusted model a priori, based on the existing literature.[19,20] Median traverse times in each group were then estimated numerically by finding the time for which the average fitted probability of the event equaled 0.5. Because overweight and obese women were oversampled in comparison with normal-weight women, bootstrapping was used to estimate standard errors for the median traverse times within each exposure group, and *P* values were derived from the normality of the median estimates.[21]

Because 18% of our study population had a first-stage cesarean delivery, we sought to pinpoint when women were censored out of our analysis and how this dropout might affect our active phase median traverse times. To this end, we first constructed a graph to depict the timing of dropout for each body mass group, according to their cervical dilation at cesarean delivery. Next, we restricted our sample to women with a vaginal delivery and reran our interval-censored models to compare the median times generated from the reduced and full sample models.

RESULTS

Table 1 presents baseline sociodemographic, medical, and behavioral characteristics of the overall study population, stratified by maternal prepregnancy BMI. Overweight women were similar to normal-weight women on most factors, but obese women had a significantly greater proportion in the younger age categories. Obese women tended to be single, African American, and have completed fewer years of education. Both overweight and obese women had a higher proportion in the excessive weight gain category, compared with normal-weight women.

Table 2 highlights the intrapartum characteristics of the study population, stratified by maternal prepregnancy BMI. Both overweight and obese women were admitted earlier (based on cervical dilation assessment) to labor and delivery, reported no or irregular uterine contractions, had their labor induced, and received oxytocin more often, compared with normal-weight women. Primary emergent cesarean delivery rates were higher for overweight (27% versus 19%, $P = .08$) and obese (27% versus 19%, $P = .04$) women compared with normal-weight women (Table 3). The majority of these deliveries were performed during the first stage of labor and based on an indication of dystocia and fetal distress. Infants of overweight and obese women were 100 g and

Table 1. Baseline Characteristics of Term, Nulliparous Women According to Their Prepregnancy Body Mass Index (Pregnancy, Infection, and Nutrition Study, 1995–2002)

	Normal (BMI 19.8–26.0 kg/m^2) (n = 297)	Overweight (BMI 26.1–29.0 kg/m^2) (n = 115)	P*	Obese (BMI > 29.0 kg/m^2) (n = 200)	$P^\dagger$
Maternal prepregnancy body mass (kg/m^2)	22.5 ± 1.7	27.4 ± 0.8	< .001	35.7 ± 6.4	< .001
Maternal height (in)	65.0 ± 2.6	64.8 ± 3.1	.60	64.7 ± 2.6	.88
Maternal age			.34		.05
< 20 y	83 (28.0)	33 (28.7)		60 (30.0)	
20–29 y	151 (50.8)	65 (58.5)		117 (58.5)	
≥ 30 y	63 (21.2)	17 (14.8)		23 (11.5)	
Mean ± SD	24.0 ± 5.8	23.6 ± 5.8		23.0 ± 5.2	
Maternal race			.59		< .001
White	173 (58.2)	69 (60.0)		88 (44.0)	
African American	100 (33.7)	39 (33.9)		104 (52.0)	
Other	24 (8.1)	7 (6.1)		8 (4.0)	
Marital status			.38		.002
Single/divorced/widowed	156 (52.7)	55 (47.8)		133 (66.5)	
Married	140 (47.3)	60 (52.2)		67 (33.5)	
Maternal education			.59		< .001
< 12 y	58 (19.5)	23 (20.0)		49 (24.5)	
12 y	61 (20.6)	28 (24.3)		72 (36.0)	
> 12 y	178 (59.9)	64 (55.7)		79 (39.5)	
Mean ± SD	14.0 ± 3.0	13.7 ± 3.0		12.8 ± 2.4	
Delivery site			.74		.58
University of North Carolina Hospitals	177 (59.6)	66 (57.4)		86 (43.0)	
Wake Medical Center	120 (40.4)	49 (42.6)		114 (57.0)	
Prenatal care type			.20		< .001
Private	108 (36.5)	34 (29.6)		40 (20.0)	
Public	188 (63.5)	81 (70.4)		160 (80.0)	
Weight gain during pregnancy			< .001		.03
Excessive	183 (69.1)	89 (85.6)		133 (78.7)	
Inadequate/adequate	82 (30.9)	15 (14.4)		36 (21.3)	
Mean ± SD (kg)	18.2 ± 6.7	16.9 ± 6.2		13.6 ± 8.5	

BMI, body mass index; SD, standard deviation.

Data are presented as n (%) or mean ± standard deviation (t test or χ^2 test). Information was not available for all covariates.

* Comparison between normal-weight and overweight women.

† Comparison between normal-weight and obese women.

60 g heavier, respectively, than infants of normal-weight women.

Overweight and obese women had a significantly longer median duration of labor from 4 to 10 cm compared with normal-weight women (7.5, 7.9, and 6.2 hours, respectively), after adjusting for maternal height, net weight gain, labor induction, membrane rupture, the timing and use of epidural analgesia, oxytocin use, and fetal size (Table 4). Upon further examination, the longer median duration of labor in overweight women was mostly attributable to the slower labor progression from 4 to 6 cm. No significant differences were seen between normal and overweight women in the remaining active phase of labor. In contrast, the longer median duration of labor in obese women was attributable to a significantly slower labor progression before 7 cm. At first glance, it appears that obese women have a marginally faster labor progression from 7 to 10 cm compared with normal-weight women. However, the reported difference may not be as clinically important (ie, 28 versus 35 minutes from 7 to 8 cm for obese and normal-weight women, respectively). These median values might also be influenced to some degree by patient dropout due to a first-stage cesarean delivery (Fig. 1). No difference in the second stage of labor was seen between normal-weight and overweight women, but obese women appear to have a faster second stage of labor. They also had more second-stage cesareans performed (7.0%) compared with normal-weight women (4.7%), a difference that, along with the first-stage cesarean deliveries, may have reduced our estimates. However, a mean difference of 15 minutes may not necessarily be relevant, from a clinical perspective.

It is possible that dropout due to a cesarean delivery before 10 cm of cervical dilation and in the second stage of labor influenced some of our results. Thus, to assess whether these trends persisted among vaginal deliveries, we fitted the same models but excluded women who

Table 2. Intrapartum Characteristics of Term, Nulliparous Women, According to Their Prepregnancy Body Mass Index (Pregnancy, Infection, and Nutrition Study, 1995–2002)

	Normal (BMI 19.8–26.0 kg/m^2) (n = 297)	Overweight (BMI 26.1–29.0 kg/m^2) (n = 115)	P*	Obese (BMI > 29.0 kg/m^2) (n = 200)	P†
Cervical dilation at admission (cm)	3.0 (1.0, 5.0)	2.5 (1.0, 6.0)	.39	2.0 (0.0, 5.0)	.03
Contractions present at admission			.47		.01
Yes, regular	181 (60.9)	63 (54.8)		90 (45.0)	
Every 1–5 min	165 (55.5)	57 (49.6)		78 (39.0)	
Every 6–15 min	16 (5.4)	6 (5.2)		12 (6.0)	
Yes, but unknown frequency	13 (4.4)	4 (3.5)		10 (5.0)	
Yes, but irregular	31 (10.4)	9 (7.8)		30 (15.0)	
No	67 (22.6)	35 (30.4)		68 (34.0)	
Unknown	5 (1.7)	4 (3.5)		2 (1.0)	
Labor onset			.22		< .001
Spontaneous	205 (69.0)	69 (60.0)		106 (53.0)	
Induction without cervical ripening	45 (15.2)	23 (20.0)		36 (18.0)	
Induction with cervical ripening	47 (15.8)	23 (20.0)		58 (29.0)	
Method of cervical ripening			.21		.11
Foley bulb	23 (7.7)	15 (13.0)		38 (19.0)	
Prostaglandins	24 (8.1)	8 (7.0)		20 (10.0)	
Received oxytocin	167 (56.2)	79 (68.7)	.02	150 (75.0)	< .001
Cervical dilation at oxytocin administration (cm)	3.0 (1.0, 8.5)	3.0 (1.0, 8.5)	.98	3.0 (1.0, 7.0)	.84
Received epidural analgesia	200 (67.3)	81 (70.4)	.64	142 (71.0)	.43
Cervical dilation at epidural analgesia placement (cm)	5.0 (3.0, 9.0)	5.0 (3.0, 9.0)	.70	5.0 (3.0, 8.0)	.72
Method of membrane rupture			< .01		.41
Spontaneous	133 (44.8)	35 (30.7)		83 (41.5)	
Artificial	159 (53.5)	80 (69.3)		117 (58.5)	
Undetermined	5 (1.7)	0 (0.0)		0 (0.0)	

BMI, body mass index.

Data are presented as n (%) or median (10th, 90th percentiles) (χ^2 test or Wilcoxon rank sum test).

* Comparison between normal-weight and overweight women.

† Comparison between normal-weight and obese women.

delivered by cesarean (Table 5). Normal-weight and overweight women had a similar median duration of labor from 4 to 10 cm. However, the general trend of a slower labor from 4 to 6 cm persisted in overweight women. Similarly, obese women maintained a significant longer median duration of labor from 4 to 10 cm, compared with normal-weight women (7.0 versus 5.4 hours, $P < .001$). And as seen in overweight women, the trend of a slower labor before 7 cm persisted in obese women. No noticeable differences were seen among groups for the remaining active phase of labor.

DISCUSSION

Previous studies on pregnancy outcomes in obese women have reported briefly on the prevalence of select characteristics of labor and delivery[8,10,22,23] or offered a crude estimate of the duration of labor.[8] However, few have explored in depth the effect of maternal overweight and obesity on labor progression after adjusting for potential confounders in current obstetric practice. The results from this study are consistent with those from previous studies that showed that obese women are more likely to have an inadequate contraction pattern during the first stage of labor[8] and to receive oxytocin for labor induction[10,23] and augmentation[8,10,23] compared with nonobese women. Oxytocin is administered to women similarly and regardless of differences in maternal weight, because of concerns of overdosing. Thus, it is possible that the drug itself or its receptors might be influenced by maternal BMI. However, further research is needed to confirm such hypotheses and is beyond the scope of this analysis.

Nonetheless, labor progression before 6 cm of cervical dilation was significantly slower in overweight and obese women compared with normal-weight women, even after adjusting for labor induction and oxytocin use. Several authors have speculated that this phenomenon may be due to the added soft-tissue deposits in the pelvis of overweight and obese women, which coupled with a larger fetus might necessitate more time and stronger

Table 3. Pregnancy Outcomes of Term, Nulliparous Women According to Their Prepregnancy Body Mass Index (Pregnancy, Infection, and Nutrition Study, 1995–2002)

	Normal (BMI 19.8–26.0 kg/m^2) (n = 297)	Overweight (BMI 26.1–29.0 kg/m^2) (n = 115)	P*	Obese (BMI > 29.0 kg/m^2) (n = 200)	$P^\dagger$
Method of delivery			.09		.07
Spontaneous vaginal	182 (61.3)	69 (60.0)		117 (58.5)	
Instrument-assisted vaginal	59 (19.9)	15 (13.0)		29 (14.5)	
Primary emergent cesarean	56 (18.8)	31 (27.0)		54 (27.0)	
Indications for primary emergent cesarean delivery					
Failure to progress	25 (8.4)	14 (12.2)		25 (12.5)	
Malpresentation	2 (0.7)	1 (0.9)		0 (0.0)	
Fetal distress	21 (7.1)	13 (11.3)		21 (10.5)	
Placental abruption	1 (0.3)	0 (0.0)		0 (0.0)	
Failed induction	0 (0.0)	2 (1.7)		5 (2.5)	
Failed forceps/vacuum delivery	5 (1.6)	1 (0.9)		2 (1.0)	
Other factors	2 (0.7)	0 (0.0)		1 (0.5)	
Timing of primary emergent cesarean					
First-stage cesarean	42 (14.1)	26 (22.6)		40 (20.0)	
Second-stage cesarean	14 (4.7)	5 (4.4)		14 (7.0)	
Infant birth weight (g)	3,385 ± 497	3,485 ± 473	.07	3,445 ± 468	.18
Macrosomia (yes)	36 (12.1)	18 (15.6)	.33	24 (12.1)	.99
Gestational age at delivery (wk)	39.47 ± 1.3	39.53 ± 1.3	.66	39.6 ± 1.3	.21

BMI, body mass index.

Data are presented as n (%) or means ± standard deviation (t test or χ^2 test).

* Comparison between normal-weight and overweight women.

† Comparison between normal-weight and obese women.

contractions to progress through labor.[5,8,24] Studies that have measured suprailiac skinfold thickness confirm perceptions that more maternal fat is accumulated centrally than peripherally during pregnancy,[25,26] especially among obese women.[27] Thus, it is possible that added soft-tissue deposits in the maternal pelvis might narrow the diameter of the birth canal and prolong labor, particularly during the second stage. However, direct evidence of fat deposition in the pelvis of overweight and obese women is needed to support this assertion and is beyond the scope of this analysis. Although we did not measure suprailiac skinfold thickness in our study, we controlled

Table 4. Adjusted Median Duration of Time Elapsed (Hours) in Labor for Each Centimeter of Cervical Dilation for Term, Nulliparous Women According to Their Prepregnancy Body Mass Index (Pregnancy, Infection, and Nutrition Study, 1995–2002)

Cervical dilation	Normal (BMI 19.8–26.0 kg/m^2) (n = 297)	Overweight (BMI 26.1–29.0 kg/m^2) (n = 115)	P*	Obese (BMI > 29.0 kg/m^2) (n = 200)	$P^\dagger$
From 4 to 10 cm	6.20	7.52	< .01	7.94	< .001
From 3 to 4 cm	1.58	1.43	.03	1.74	.17
From 4 to 5 cm	1.41	1.63	.06	1.69	< .01
From 5 to 6 cm	0.80	0.98	< .001	1.27	< .001
From 6 to 7 cm	0.64	0.61	.33	0.80	< .001
From 7 to 8 cm	0.58	0.60	.47	0.47	< .001
From 8 to 9 cm	0.49	0.51	.46	0.46	.02
From 9 to 10 cm	0.45	0.44	.65	0.49	.02
Second stage of labor (geometric mean, min)	62.7	60.2	.73	47.4	.01

BMI, body mass index.

An interval-censored regression model with a log normal distribution was fitted to adjust for maternal height, membrane rupture, epidural analgesia, timing of epidural analgesia placement, labor induction, oxytocin use, net maternal weight gain, and fetal size.

* Comparison between normal-weight and overweight women.

† Comparison between normal-weight and obese women.

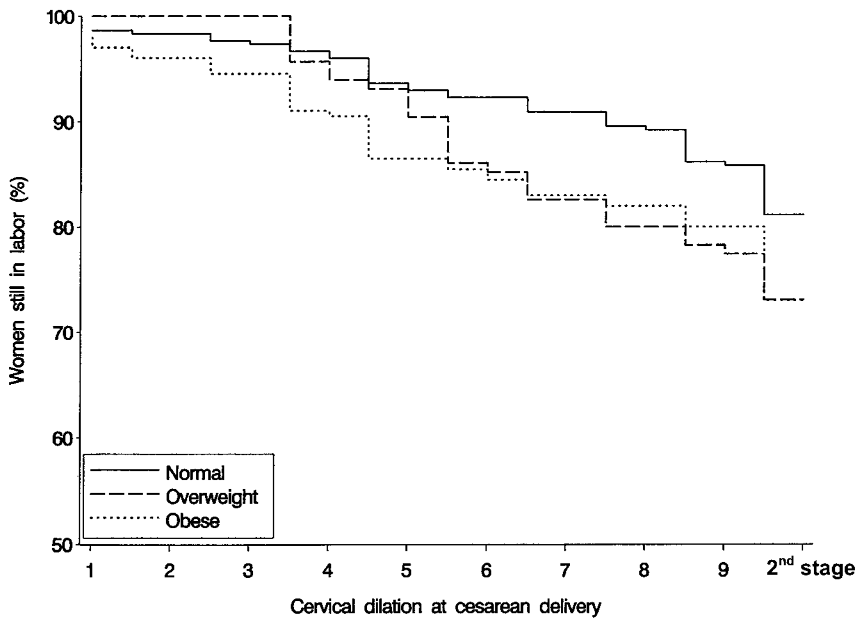

Fig. 1. Timing of dropout because of cesarean delivery, according to cervical dilation at delivery, Pregnancy, Infection, and Nutrition Study, 1995–2002.

Vahratian. Labor Progression in Overweight and Obese Women. Obstet Gynecol 2004.

for factors such as maternal height, net maternal weight gain, and fetal size in our analysis. Even after adjustment, the significant trend remained before 6 cm.

The findings of this study must be interpreted with recognition of its limitations. First, the measurement of cervical dilation was subjective. Continuous monitoring of cervical dilation was not performed and the measurements were based on vaginal examinations performed by several physicians. This potential misclassification would likely be nondifferential in nature and would bias our results toward the null. Second, there is a concern surrounding informative censoring. Obese women were more likely to have a first-stage cesarean delivery compared with overweight and normal-weight women. As illustrated in Figure 1, more obese women dropped out of our interval-censored regression analysis earlier than the other two groups. Although adjustment for selected factors was performed to reduce selection bias in this instance, time intervals for more advanced cervical dilation were affected to an extent by dropout of women with protracted labor in both overweight and obese women.

Third, the recruitment period for the study excluded women who obtained prenatal care in the third trimester or not at all, excluding some higher-risk women and limiting the generalizability of the findings. Lastly, be-

Table 5. Adjusted Median Duration of Time Elapsed (Hours) in Labor for Each Centimeter of Cervical Dilation for Term, Nulliparous Women With a Vaginal Delivery, According to Their Prepregnancy Body Mass Index (Pregnancy, Infection, and Nutrition Study, 1995–2002)

Cervical dilation	Normal (BMI 19.8–26.0 kg/m^2) (n = 241)	Overweight (BMI 26.1–29.0 kg/m^2) (n = 84)	*P**	Obese (BMI > 29.0 kg/m^2) (n = 146)	*P*†
From 4 to 10 cm	5.43	5.54	.73	6.98	< .001
From 3 to 4 cm	1.58	1.38	.11	1.27	.01
From 4 to 5 cm	1.40	1.43	.82	1.29	.24
From 5 to 6 cm	0.66	0.98	< .001	0.98	< .001
From 6 to 7 cm	0.57	0.56	.92	0.62	.13
From 7 to 8 cm	0.43	0.46	.29	0.44	.63
From 8 to 9 cm	0.42	0.39	.04	0.40	.17
From 9 to 10 cm	0.38	0.35	.11	0.35	< .01

BMI, body mass index.

An interval-censored regression model with a log normal distribution was fitted to adjust for maternal height, membrane rupture, epidural analgesia, timing of epidural analgesia placement, labor induction, oxytocin use, net maternal weight gain, and fetal size.

* Comparison between normal-weight and overweight women.

† Comparison between normal-weight and obese women.

cause of the observational nature of our data, we cannot entirely exclude the possibility that important confounders were omitted from the analysis or that adjustment for confounders was incomplete. Limited information was available on physician factors that may influence labor progression and increase the risk for cesarean delivery. Thus, the presence of residual confounding is possible. Moreover, we acknowledge that the patterns observed in our data may be in part the result of random error, given the small numbers in some cells.

Nonetheless, this study has several strengths. Few studies to date have examined the characteristics of labor and delivery for overweight and obese women. In contrast, this study abstracted detailed intrapartum data to examine the relationship between maternal prepregnancy weight status and the pattern of labor progression in term, nulliparous women. This information allowed us to document differences in the prevalence of obstetric interventions among normal-weight, overweight, and obese women. In general, more advanced statistical methods were used in this study, which further allowed us to examine labor progression centimeter-by-centimeter.

In our study, overweight and obese women had a significantly slower labor from 4 to 10 cm, compared with that of normal-weight women. In particular, the pattern of labor progression for obese women was significantly slower than that of normal-weight women before 7 cm. Given that nearly one half of women of childbearing age are either overweight or obese, it is critical to consider differences in labor progression by maternal prepregnancy BMI before additional interventions are performed.

REFERENCES

1. Cogswell ME, Perry GS, Schieve LA, Dietz WH. Obesity in women of childbearing age: risks, prevention, and treatment. Prim Care Update Ob Gyns 2001;8:89–105.
2. 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;187:312–20.
3. Shepard MJ, Saftlas AF, Leo-Summers L, Bracken MB. Maternal anthropometric factors and risk of primary cesarean delivery. Am J Public Health 1998;88:1534–8.
4. Kaiser PS, Kirby RS. Obesity as a risk factor for cesarean in a low risk population. Obstet Gynecol 2001;97:39–43.
5. Crane SS, Wojtowycz MA, Dye TD, Aubry RH, Artal R. Association between pre-pregnancy obesity and the risk of cesarean delivery. Obstet Gynecol 1997;89:213–6.
6. 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.
7. Baeten JM, Bukusi EA, Lambe M. Pregnancy complications and outcomes among overweight and obese nulliparous women. Am J Public Health 2001;91:436–40.
8. Jensen H, Agger AO, Rasmussen KL. The influence of prepregnancy body mass index on labor complications. Acta Obstet Gynecol Scand 1999;78:799–802.
9. 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;92:501–6.
10. Johnson SR, Kolberg BH, Varner MW, Railsback LD. Maternal obesity and pregnancy. Surg Gynecol Obstet 1987;164:431–7.
11. Savitz DA, Dole N, Williams J, Thorp JM, McDonald T, Carter AC, et al. Determinants of participation in an epidemiological study of preterm delivery. Paediatr Perinat Epidemiol 1999;13:114–25.
12. Institute of Medicine. Nutrition during pregnancy. Part I. Weight gain; Part II. Nutrient supplements. Washington, DC: National Academy Press; 1990.
13. Siega-Riz AM, Adair LS, Hobel CJ. Institute of Medicine maternal weight gain recommendations and pregnancy outcome in a predominately Hispanic population. Obstet Gynecol 1994;84:565–73.
14. Stevens-Simon C, Roghmann KJ, McAnarney ER. Relationship of self-reported prepregnant weight and weight gain during pregnancy to maternal body habitus and age. J Am Diet Assoc 1992;92:85–7.
15. Rowland ML. Self-reported weight and height. Am J Clin Nutr 1990;52:1125–33.
16. Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: Findings from the third National Health and Nutrition Examination Survey, 1988–1994. J Am Diet Assoc 2001;101:28–34.
17. Klein JP, Moeschberger ML. Survival analysis: techniques for censored and truncated data. Berlin: Springer; 1997.
18. Allison PD. Survival analysis using the SAS system: a practical guide. Cary (NC): SAS Institute Inc; 1995. p. 97.
19. Flegal KM, Launer LJ, Graubard BI, Kestler E, Villar J. Modeling maternal weight and height in studies of pregnancy outcome among Hispanic women. Am J Clin Nutr 1993;58:145–51.
20. Vahratian A, Zhang J, Hasling J, Troendle JF, Klebanoff MA, Thorp JM Jr. The effect of early epidural versus intravenous analgesia use on labor progression: a natural experiment. Am J Obstet Gynecol 2004;191:259–65.
21. Efron B. The jackknife, the bootstrap, and other resampling plans. Philadelphia (PA): Society for Industrial and Applied Mathematics; 1982.

22. Gross TL, Sokol RJ, King KC. Obesity in pregnancy: risks and outcome. Obstet Gynecol 1980;56:446–50.
23. Edwards LE, Hellerstedt WL, Alton IR, Story M, Himes JH. Pregnancy complications and birth outcomes in obese and normal-weight women: Effects of gestational weight change. Obstet Gynecol 1996;87:389–94.
24. Garbaciak Jr. JA, Richter M, Miller S, Barton JJ. Maternal weight and pregnancy complications. Am J Obstet Gynecol 1985;152:238–45.
25. Soltani H, Fraser RB. A longitudinal study of maternal anthropometric changes in normal weight, overweight, and obese women during pregnancy and postpartum. Br J Nutr 2000;84:95–101.
26. Taggart NR, Holliday RM, Billewicz WZ, Hytten WZ, Thomson AM. Changes in skinfolds during pregnancy. Br J Nutr 1967;21:439–51.
27. Ehrenberg HM, Huston-Presley L, Catalano PM. The influence of obesity and gestational diabetes mellitus on accretion and the distribution of adipose tissue in pregnancy. Am J Obstet Gynecol 2003;189:944–8.

Reprints are not available. Address correspondence to: Anjel Vahratian, PhD, MPH, Department of Obstetrics and Gynecology, The University of Michigan, L4000 Women's Hospital, 1500 East Medical Center Drive, Ann Arbor, MI 48108–0276; e-mail: amv@med.umich.edu.

Received April 26, 2004. Received in revised form June 26, 2004. Accepted July 8, 2004.