

Maternal weight, pregnancy weight gain, and the risk of antepartum stillbirth

Olof Stephansson, MD, Paul W. Dickman, PhD, Anna Johansson, MSc, and Sven Cnattingius, MD, PhD

Stockholm, Sweden

OBJECTIVE: This study investigated whether the risk of antepartum stillbirth increases with body mass index during early pregnancy and also investigated the association between weight gain during pregnancy and the risk of antepartum stillbirth.

STUDY DESIGN: This population-based case-control study included 649 women with antepartum stillbirths and 690 control subjects among Swedish nulliparous women.

RESULTS: Compared with lean mothers (body mass index ≤ 19.9 kg/m²), the odds ratios for risk of antepartum deaths were as follows: normal weight (body mass index, 20.0-24.9 kg/m²) odds ratio, 1.2 (95% confidence interval, 0.8-1.7); overweight (body mass index 25.0-29.9 kg/m²), odds ratio, 1.9 (95% confidence interval, 1.2-2.9); and obese (body mass index ≥ 30.0 kg/m²) odds ratio, 2.1 (95% confidence interval, 1.2-3.6). For term antepartum death corresponding risks were even higher, with odds ratios of 1.6 (95% confidence interval, 0.9-2.6) for normal weight, 2.7 (95% confidence interval, 1.5-5.0) for overweight, and 2.8 (95% confidence interval, 1.3-6.0) for obese women, respectively. Maternal weight gain during pregnancy was not associated with risk of antepartum stillbirth.

CONCLUSION: Maternal overweight condition increased the risk of antepartum stillbirth, especially term antepartum stillbirth, whereas weight gain during pregnancy was not associated with risk. (Am J Obstet Gynecol 2001;184:463-9.)

Key words: Body mass index, pregnancy, risk factors, stillbirth, weight gain

Stillbirth accounts for more than a third of all fetal and infant deaths and for >50% of perinatal deaths in Europe and North America.¹⁻³ Although causes of stillbirth often differ from causes of death during the first week of life,^{4,5} relatively few studies have specifically focused on risk factors for stillbirth.⁶

An association between prepregnancy body mass index and stillbirth has been reported, with the lowest risk among lean women and the highest risk among obese women.⁷ A Swedish registry-based study found that the overall risk of stillbirth consistently increased with body mass index, with a 4-fold increase in risk observed among obese nulliparous women relative to lean nulliparous women.⁸ Maternal overweight condition is, however, associated with other possible risk factors for stillbirth, such as low social status and maternal diseases, which were only partly accounted for in previous studies.^{7,8} The relationship between weight gain during pregnancy, mater-

nal weight, and the risk of stillbirth is today relatively uncertain.^{9,10}

Being overweight is common among young women today.^{11,12} If results from previous studies are confirmed, being overweight may be one of the most important risk factors for stillbirth in developed countries. In this large population-based case-control study on nulliparous women, we retrieved prospectively collected data from unit records to investigate the association between body mass index during early pregnancy, weight gain during pregnancy, and the risk of antepartum death before and after adjustment for a number of covariates.

Material and methods

Description of sample. From the Swedish Medical Birth Register, which includes information on practically all births in Sweden,¹³ we obtained information on all single births to nulliparous women who lived and were delivered within a geographically defined area in central Sweden from 1987 through 1996. Among 220,712 recorded births, there were 725 stillbirths (case group) occurring at ≥ 28 weeks' gestation. For each case patient we randomly selected 2 control subjects matched for year of birth and delivery hospital. By means of the unique national registration number assigned to all Swedish residents, the standardized antenatal and obstetric records were retrieved from each of the 25 delivery hospital archives and examined by one of us (Olof Stephansson)

From the Department of Medical Epidemiology, Karolinska Institutet. Supported by The Swedish Council for Social Research (project 98-0265:1B) and by grants from Karolinska Institutet.

Received for publication February 1, 2000; revised May 31, 2000; accepted June 20, 2000.

Reprint requests: Olof Stephansson, MD, Department of Medical Epidemiology, Karolinska Institutet, PO Box 281, SE-171 77 Stockholm, Sweden.

Copyright © 2001 by Mosby, Inc.

0002-9378/2001 \$35.00 + 0 6/1/109591

doi:10.1067/mob.2001.109591

according to a structured protocol. Among the 725 eligible case patients, information was obtained for 702 (97%): 10 case records were missing in the archives, 8 were incorrectly coded for delivery hospital, and 5 had incorrect national registration numbers and were therefore impossible to trace. With respect to the control subjects, the second control subject was included only if information was not found for the first selected control subject. To obtain equal numbers of case patients and control subjects ($n = 702$), 25 second-choice control subjects were included, because 24 of the first-choice control subjects were missing in the archives and 1 had an incorrect national registration number (retrieval rate of first control information of 97%). Four case patients and 2 control subjects had not received antenatal care, and 12 case patients and 4 control subjects did not have complete antenatal records. Because risk factors for antepartum and intrapartum stillbirth differ,⁷ the current analysis was restricted to antepartum stillbirths ($n = 649$ case patients and $n = 690$ individually matched control subjects).

In antenatal records information is prospectively recorded from the first to the last antenatal visit. At registration for antenatal care we obtained information about maternal height, weight, number of previous miscarriages, induced abortions, extrauterine pregnancies, occupation, cigarette smoking, alcohol consumption, years of involuntary childlessness, and gestational age at admission to antenatal care. History of maternal diseases at registration was noted and classified according to the Swedish version of the *International Classification of Diseases, Ninth Revision*.¹⁴ Information about expected date of delivery was calculated from second-trimester ultrasonographic examination (generally before 19 gestational weeks) when available (94% of case patients and control subjects); otherwise, the last menstrual period was used.

During pregnancy we obtained information about maternal weight, blood pressure, proteinuria, blood glucose level, glucosuria, results of 75-g oral glucose tolerance test (when performed), and pregnancy complications. Preeclampsia and eclampsia were diagnosed according to the criteria given by the National High Blood Pressure Education Program Working Group Report on High Blood Pressure in Pregnancy.¹⁵ Mild preeclampsia was considered to be gestational hypertension (blood pressure $\geq 140/90$ mm Hg in at least 2 readings ≥ 6 hours apart, occurring after 20 weeks' gestation) accompanied by mild or moderate proteinuria (2 urinary dipstick readings of 1+ or 2+ or 300 mg–3 g protein in a 24-hour urine collection). Severe preeclampsia was considered to be gestational hypertension accompanied by severe proteinuria (2 urinary dipstick readings of 3+ or ≥ 3 g protein in a 24-hour urine collection) or gestational hypertension with a diastolic blood pressure ≥ 110 mm Hg (in at least 2

readings ≥ 6 hours apart) regardless of proteinuria. Eclampsia was considered to be seizures in a patient with preeclampsia that could not be attributed to other causes. Gestational diabetes was a fasting blood glucose level of ≥ 6.7 mmol/L or a 75-g oral glucose tolerance test value of ≥ 9 mmol/L after 120 minutes. If the blood glucose level at any time during pregnancy was >6.5 mmol/L, we considered this to represent suspected gestational diabetes. We obtained information about maternal age at delivery, gestational age at birth, and gestational age at diagnosed antepartum death from the obstetric and pediatric records.

Body mass index at registration for antenatal care was calculated as the weight in kilograms divided by the square of height in meters. Women were categorized as having lean weight (body mass index <20.0 kg/m²), normal weight (body mass index 20.0–24.9 kg/m²), overweight (body mass index 25.0–29.9 kg/m²), or obesity (body mass index ≥ 30.0 kg/m²). Weight gains in kilograms per week during early and late pregnancy were calculated according to the method described here and classified into 7 groups. Histories of miscarriages, induced abortions, and extrauterine pregnancies were grouped as no event or at least one event. Occupations of case patients and control subjects were classified according to the Swedish Socioeconomic Classification¹⁶ and grouped as follows: blue-collar workers, low-level white-collar workers, intermediate- and high-level white-collar workers, students, and others (not in labor force, $n = 51$; not classifiable, $n = 78$). Maternal smoking was categorized as no daily smoking, 1 to 9 cigarettes/d, or ≥ 10 cigarettes/d. Alcohol consumption at registration was categorized according to whether the woman had never been or had ever been a drinker during pregnancy. Involuntary childlessness was grouped as <1 year, 1 to 2 years, and ≥ 3 years. First attendance for antenatal care was categorized as before gestational week 13, gestational weeks 13 through 15, and gestational week 16 onward. Maternal diseases were grouped into pregestational diabetes ($n = 15$ [type 1, $n = 14$; type 2, $n = 1$]), essential hypertension ($n = 41$), other systemic diseases ($n = 22$ [Charcot-Marie-Tooth disease, $n = 2$; rheumatism, $n = 3$; rheumatoid arthritis, $n = 1$; Crohn disease, $n = 3$; multiple sclerosis, $n = 1$; psoriatic arthritis, $n = 1$; ulcerative colitis, $n = 5$; renal disease, $n = 3$; and systemic lupus erythematosus, $n = 3$]), and infectious diseases ($n = 14$ [human immunodeficiency virus infection, $n = 1$; hepatitis B, $n = 7$; hepatitis C, $n = 4$; malaria, $n = 1$; and lung tuberculosis, $n = 1$]).

Average weekly weight gains in kilograms per week were estimated separately for early and late pregnancy periods by means of simple linear regression. For the purpose of modeling weight gain, the start of the early period was defined as the week of gestation closest to gestational week 14, provided that it was between gestational weeks 4 and 20. The end of the early period was de-

defined as the week of gestation closest to gestational week 25, provided that it was between gestational weeks 18 and 31. The regression line for the early period was fitted to all weight measurements during that period. The estimated weekly weight gain was given by the estimated slope of the fitted regression line. The method of estimating average weekly weight gain for the late period was similar, with the start week being identical to the end week of the early period and the end week defined as the week of gestation closest to gestational week 38, provided that it was between gestational weeks 28 and 41. Average weekly weight gain was not estimated if the difference between the start and end dates of the period was <3 weeks. Among case patients we used weight information only from before antepartum death. The effect of average weekly weight gain during the late period was only assessed in the analysis of term antepartum deaths, because late period weight gain data were often insufficient for preterm deaths.

The study was approved by the research ethics committee at Karolinska Institutet, Stockholm.

Statistical methods. The data were entered into the computer in the Paradox (Inprise Corporation, Scotts Valley, Calif) database-management system according to a standardized protocol. The analysis was performed with conditional logistic regression by means of the Statistical Analysis Software routine PROC PHREG (SAS Institute, Inc, Cary, NC), in which pairs with identical values for the matching variables were combined into the same stratum¹⁷; that is, the data were analyzed as if they were N:M matched (each stratum contained N controls and M cases but neither N nor M was necessarily 1). All 702 control subjects were eligible for the analysis, but they were included only if they belonged to a stratum that contained ≥ 1 case patient, which allowed 690 control subjects to be considered for inclusion in the analysis. For each model, observations with missing values for explanatory variables were excluded from the analysis, although the corresponding matched case patient or control subject was included in the analysis if the stratum contained ≥ 1 case patient and ≥ 1 control subject with full covariate information. Odds ratios with 95% confidence intervals were used to estimate the relative risks.

Results

In the univariate analysis being overweight (body mass index 25.0-29.9 kg/m²) and being obese (body mass index ≥ 30.0 kg/m²) carried a ≥ 2 -fold increase in risk of antepartum death relative to lean women (body mass index ≤ 19.9 kg/m²; Table I). Maternal weight gains during early and late pregnancy were not associated with risk of antepartum death, except for the lowest weight gain group (≤ 0.24 kg/wk) during both the early and late periods (odds ratios, 1.7 and 1.8, respectively). There was an increased risk of antepartum death with advancing age, lower socioeco-

omic status, cigarette smoking, involuntary childlessness for ≥ 3 years, and diabetes mellitus, whereas risks associated with a short maternal stature, essential hypertension, preeclampsia or eclampsia, and suspected and manifest gestational diabetes were of borderline significance or were not significantly increased. Previous miscarriages, induced abortions, extrauterine pregnancies, alcohol consumption, gestational week at registration, and systemic and infectious diseases did not affect risk of antepartum death (data available on request).

Maternal pregnancy weight gains for the different body mass index groups are shown in Table II. Average weekly weight gain in early pregnancy was lower among women in the highest body mass index category relative to other body mass index groups. There was no clear association between body mass index and average weekly weight gain during late pregnancy. Overweight and obese women were more often blue-collar workers, were more frequently cigarette smokers (especially >10 cigarettes/d), and were more likely to have essential hypertension, gestational diabetes, and preeclampsia or eclampsia (data available on request).

On the basis of the results of the univariate analysis, multiple regression analysis was performed (Table III). Overweight and obese women faced a 2-fold increase in risk of antepartum death relative to lean women. The risk of antepartum death consistently increased with maternal age and was increased among women with short stature, blue-collar workers, low-level white-collar workers, and students. Daily smoking was associated with a dose-dependent increase in risk. It was not possible to include diabetes mellitus as a covariate, because the only control subject with diabetes mellitus had missing data for other covariates. Involuntary childlessness, gestational week at registration, and essential hypertension were tested but not found significant (data available on request). Because women who were delivered in 1992 and 1993 were also included in a previous study,⁸ we performed a separate analysis in which case patients (n = 134) and control subjects (n = 141) who were delivered in 1992 and 1993 were excluded. Only minor changes were seen in the estimates made with the reduced data set (data available on request).

Early pregnancy weight gain was then included in the analysis but was not found to be significantly associated with risk of antepartum death ($P = .23$). The estimated odds ratio for weight gain was highest for the group with the lowest weight gain (odds ratio, 1.5; 95% confidence interval, 0.9-2.7). When weight gain was included as a covariate, the odds ratio for obese women decreased from 2.1 (95% confidence interval, 1.2-3.6) to 1.7 (95% confidence interval, 0.9-3.1). Thus the effect of body mass index was to a small degree confounded by early pregnancy weight gain. An interaction between body mass index and early pregnancy weight gain, however, was not found to be statistically significant ($P = .15$).

Table I. Characteristics of primiparous women with antepartum deaths and matched control subjects, crude odds ratios, and 95% confidence intervals for risk of antepartum death, Sweden, 1987-1996

Characteristic	Antepartum death (n = 649)		Control (n = 690)		Odds ratio	
	No.	%	No.	%	Crude	95% Confidence interval
Body mass index						
≤19.9 kg/m ² *	68	10.5	104	15.1	1.0	Referent
20.0-24.9 kg/m ²	358	55.2	434	62.9	1.2	0.9-1.7
25.0-29.9 kg/m ²	142	21.9	102	14.8	2.1	1.4-3.1
≥30.0 kg/m ²	53	8.2	31	4.5	2.4	1.4-4.2
Data missing	28	4.3	19	2.8	—	—
Weight gain during early pregnancy						
≤0.24 kg/wk	86	13.3	71	10.3	1.7	1.0-2.8
0.25-0.34 kg/wk	84	12.9	106	15.4	1.1	0.7-1.9
0.35-0.44 kg/wk	113	17.4	134	19.4	1.2	0.7-1.9
0.45-0.54 kg/wk	124	19.1	126	18.3	1.4	0.9-2.3
0.55-0.64 kg/wk	89	13.7	93	13.5	1.4	0.8-2.3
0.65-0.74 kg/wk	40	6.2	59	8.6	1.0	0.5-1.7
≥0.75 kg/wk*	39	6.0	55	8.0	1.0	Referent
Data missing	74	11.4	46	6.7	—	—
Weight gain during late pregnancy						
≤0.24 kg/wk	63	9.7	47	6.8	1.8	1.1-2.9
0.25-0.34 kg/wk	62	9.6	74	10.7	1.1	0.7-1.8
0.35-0.44 kg/wk	69	10.6	99	14.4	0.9	0.6-1.4
0.45-0.54 kg/wk	91	14.0	128	18.6	0.9	0.6-1.4
0.55-0.64 kg/wk	83	12.8	112	16.2	0.9	0.6-1.4
0.65-0.74 kg/wk	52	8.0	63	9.1	1.1	0.7-1.7
≥0.75 kg/wk*	87	13.4	115	16.7	1.0	Referent
Data missing	142	21.9	52	7.5	—	—
Age						
≤19 y	32	4.9	45	6.5	0.9	0.6-1.5
20-24 y*	188	29.0	241	34.9	1.0	Referent
25-29 y	238	36.7	247	35.8	1.2	1.0-1.6
30-34 y	128	19.7	122	17.7	1.4	1.0-1.9
≥35 y	63	9.7	35	5.1	2.4	1.5-3.8
Height						
≤159 cm	96	14.8	69	10.0	1.4	1.0-2.1
160-164 cm	164	25.3	178	25.8	0.9	0.7-1.2
165-169 cm*	195	30.1	199	28.8	1.0	Referent
≥170 cm	172	26.5	227	32.9	0.8	0.6-1.0
Data missing	22	3.4	17	2.5	—	—
Occupation						
Blue-collar workers	277	42.7	254	36.8	1.5	1.2-2.0
Low-level white-collar workers	113	17.4	112	16.2	1.4	1.0-2.0
Intermediate- and high-level white-collar workers*	139	21.4	194	28.1	1.0	Referent
Students	56	8.6	54	7.8	1.4	0.9-2.2
Others	64	9.9	76	11.0	1.2	0.8-1.8
Cigarette smoking at registration for antenatal care						
None*	444	68.4	530	76.8	1.0	Referent
1-9 cigarettes/d	107	16.5	89	12.9	1.5	1.1-2.0
≥10 cigarettes/d	81	12.5	59	8.6	1.8	1.2-2.5
Data missing	17	2.6	12	1.7	—	—
Involuntary childlessness						
<1 y*	570	87.8	633	91.7	1.0	Referent
1-2 y	25	3.9	31	4.5	0.9	0.5-1.6
≥3 y	47	7.2	26	3.8	2.0	1.2-3.4
Data missing	7	1.1	0	0.0	—	—
Diabetes mellitus						
Yes	14	2.2	1	0.1	15.2	2.0-116.0
No*	635	97.8	689	99.9	1.0	Referent
Essential hypertension						
Yes	25	3.9	16	2.3	1.7	0.9-3.2
No*	624	96.2	674	97.7	1.0	Referent
Preeclampsia or eclampsia						
Mild preeclampsia	45	6.9	40	5.8	1.2	0.8-1.9
Severe preeclampsia or eclampsia	38	5.9	23	3.3	1.8	1.0-3.0
Neither*	566	87.2	627	90.9	1.0	Referent
Gestational diabetes mellitus						
Suspected gestational diabetes mellitus	74	11.4	58	8.4	1.5	1.0-2.1
Manifest gestational diabetes mellitus	9	1.4	5	0.7	2.1	0.7-6.4
Neither*	566	87.2	627	90.9	1.0	Referent

Some percentages do not add to 100.0% because of rounding.

*Reference group.

Table II. Body mass index and mean weight gain during early and late pregnancy among case patients and control subjects, Sweden, 1987-1996

Body mass index (kg/m ²)	Mean weight gain (kg/wk)	
	Early pregnancy (n = 1219)	Late pregnancy (n = 1145)
≤19.9	0.48 ± 0.19	0.53 ± 0.22
20.0-24.9	0.48 ± 0.19	0.54 ± 0.26
25.0-29.9	0.44 ± 0.23	0.55 ± 0.30
≥30.0	0.35 ± 0.23	0.50 ± 0.29
Data missing	0.41 ± 0.19	0.52 ± 0.23

Values are mean ± SD.

Table III. Adjusted odds ratios and 95% confidence intervals for antepartum deaths, Sweden, 1987-1996

Characteristic	Odds ratio	
	Adjusted	95% Confidence interval
Body mass index		
≤19.9 kg/m ² *	1.0	Referent
20.0-24.9 kg/m ²	1.2	0.8-1.7
25.0-29.9 kg/m ²	1.9	1.2-2.9
≥30.0 kg/m ²	2.1	1.2-3.6
Age		
≤19 y	0.8	0.5-1.4
20-24 y*	1.0	Referent
25-29 y	1.5	1.1-2.0
30-34 y	1.6	1.1-2.3
≥35 y	2.7	1.6-4.5
Height		
≤159 cm	1.5	1.0-2.2
160-164 cm	0.9	0.7-1.3
165-169 cm*	1.0	Referent
≥170 cm	0.8	0.6-1.1
Occupation		
Blue-collar workers	1.6	1.2-2.2
Low-level white-collar workers	1.4	1.0-2.0
Intermediate- and high-level white-collar workers*	1.0	Referent
Students	1.8	1.1-3.0
Others	1.1	0.7-1.7
Cigarette smoking at registration for antenatal care		
Nonsmoking*	1.0	Referent
1-9 cigarettes/d	1.4	1.0-1.9
≥10 cigarettes/d	1.6	1.1-2.4

Case patients, n = 613; control subjects, n = 660.

*Reference group.

To evaluate weight gain during late pregnancy we analyzed a subset of term antepartum deaths (≥37 completed gestational weeks; Table IV). Overweight and obese women faced an almost 3-fold increase in risk of term antepartum death relative to lean women. Compared with risk of all antepartum deaths, the age-related risks were higher for term antepartum deaths, with a 4-fold risk increase observed for those aged ≥35 years, whereas cigarette smoking was no longer significantly associated with

Table IV. Adjusted odds ratios and 95% confidence intervals for term antepartum deaths, Sweden, 1987-1996

Characteristic	Odds ratio	
	Adjusted	95% Confidence interval
Body mass index		
≤19.9 kg/m ² *	1.0	Referent
20.0-24.9 kg/m ²	1.6	0.9-2.6
25.0-29.9 kg/m ²	2.7	1.5-5.0
≥30.0 kg/m ²	2.8	1.3-6.0
Age		
≤19 y	0.6	0.3-1.2
20-24 y*	1.0	Referent
25-29 y	1.5	1.0-2.2
30-34 y	2.0	1.3-3.2
≥35 y	3.6	1.8-7.2
Height		
≤159 cm	1.4	0.8-2.3
160-164 cm	0.8	0.5-1.2
165-169 cm*	1.0	Referent
≥170 cm	0.6	0.4-0.9
Occupation		
Blue-collar workers	2.0	1.3-3.1
Low-level white-collar workers	1.6	1.0-2.7
Intermediate- and high-level white-collar workers*	1.0	Referent
Students	3.4	1.8-6.5
Others	1.7	0.9-3.1
Cigarette smoking at registration for antenatal care		
Nonsmoking*	1.0	Referent
1-9 cigarettes/d	1.0	0.6-1.6
≥10 cigarettes/d	1.2	0.7-2.1

Case patients, n = 302; control subjects, n = 528.

*Reference group.

risk when term antepartum deaths were considered. There was no risk associated with weight gains during early or late pregnancy (data available on request).

Next we wanted to investigate whether the effect of being overweight on the risk of antepartum death was mediated by increased rates of weight-related pregnancy complications. After exclusion of case patients and control subjects with gestational diabetes, preeclampsia, and eclampsia, the overall risk of antepartum death was increased among overweight women, whereas the risk was decreased and was no longer significant among obese women (Table V). With respect to term antepartum death, this analysis resulted in only minor changes in risks.

Comment

In this investigation we found that the conditions of overweight and obesity during early pregnancy were associated with substantially increased risks of antepartum death, foremost term antepartum death. In contrast to previous investigations,^{7,8} we did not find that the risk of antepartum death was increased for women with normal weight relative to lean women. Maternal weight gain dur-

Table V. Adjusted odds ratios and 95% confidence intervals for antepartum and term antepartum deaths among case patients and control subjects without gestational diabetes mellitus or preeclampsia or eclampsia, Sweden, 1987-1996

Body mass index (kg/m ²)	All antepartum deaths*		Term antepartum deaths†	
	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
≤19.9‡	1.0	Referent	1.0	Referent
20.0-24.9	1.2	0.8-1.8	1.7	1.0-3.1
25.0-29.9	2.5	1.5-4.0	3.5	1.7-7.2
≥30.0	1.5	0.7-3.0	2.9	1.1-7.7

*Case patients, n = 461; control subjects, n = 546. The estimates were adjusted for maternal age, height, occupation, smoking, and weight gain during early pregnancy.

†Case patients, n = 225; control subjects, n = 415. The estimates were adjusted for maternal age, height, occupation, smoking, and weight gains during early and late pregnancy.

‡Reference group.

ing early and late pregnancy was not associated with risk of antepartum death.

In this large population-based case-control study we were able to retrieve 97% of the medical records, which minimized the possibility of selection bias. Because exposure was registered prospectively during pregnancy in the antenatal records, recall bias is almost inconceivable. Possible confounders, such as maternal age, socioeconomic status, and smoking, were accounted for in the analyses. The relatively homogeneous population in Sweden, the standardized antenatal care, and the use of uniform records further minimized the possibility of confounding related to differences in sociodemographic factors or pregnancy management. We investigated primiparous women with singleton pregnancies, and the conclusions from this study can therefore only be interpreted for this group. We were restricted to data found in the archive files and could not investigate other covariates, such as energy intake or expenditure.

The mechanisms for the body mass index-related increases in risks for antepartum death remain a matter of speculation. Pregnancy complications, such as gestational diabetes and preeclampsia or eclampsia, are more common among overweight and obese women. When women with these complications were excluded from the analysis, the risk of antepartum death decreased among obese women, whereas this effect was not found for overweight women. Obesity is strongly associated with hyperlipidemia, which may directly or indirectly, through lipid peroxidases, damage endothelial cells and promote vasoconstriction and platelet aggregation, which in turn could contribute to the process of preeclampsia.¹⁸ Overweight and obese women were more often blue-collar workers and cigarette smokers than were lean and normal-weight women, which suggests that additional weight-related differences in lifestyle, such as physical activity and dietary factors, may have been present.

In accordance with previous investigations, we found that pregnancy weight gain could be described by a linear

function within the second and third trimesters and that obese women gained less weight during pregnancy.^{19, 20} Low maternal weight gain is an important determinant of intrauterine growth restriction,^{19, 21, 22} which in turn is closely associated with the risk of stillbirth. In this study we used weight measurements performed by midwives throughout the pregnancy and included no measurements after the diagnosis of stillbirth. Our finding that weight gain during pregnancy was not associated with the risk of antepartum death is supported by a previous study in which information about other covariates was not included.¹⁰ A study by Taffel et al⁹ showed an association between low weight gain and stillbirth, especially among women with low prepregnancy weight. Weight gain in that study was measured as the difference between prepregnancy weight and weight at delivery, however, and the possible influences of other covariates were not considered in a multivariate analysis.

Cigarette smoking and older maternal age are recognized risk factors for stillbirth.^{1, 5-7} When we restricted the analysis to term antepartum death, the risk associated with cigarette smoking disappeared, whereas the risk of a high maternal age became more pronounced. These findings are supported by a previous study in which the smoking-related risk of stillbirth was largest early in the third trimester and then gradually declined with advancing gestational age, whereas the age-related risk of fetal death increased with gestational age.⁶

There is a trend toward increasing prevalences of the conditions of overweight and obesity among women in many developed countries, including the United States and Sweden,^{11, 12, 23} and the conditions of overweight and obesity are related to several chronic diseases. Furthermore, a direct association between high body mass index and mortality rate among women has been reported.²⁴ Our findings suggest that in Sweden being overweight may currently be of more importance than smoking in determining the risk of antepartum death, which further emphasizes the importance of reducing the

prevalence of the overweight condition among women. The underlying mechanisms for the association between body mass index and risk of antepartum death are uncertain and require further studies. There seems to be no need for specific advice regarding pregnancy weight gain and risk of antepartum death.

REFERENCES

1. Fretts RC, Schmittiel J, McLean FH, Usher RH, Goldman MB. Increased maternal age and the risk of fetal death. *N Engl J Med* 1995;333:953-7.
2. Kalter H. Five-decade international trends in the relation of perinatal mortality and congenital malformations: stillbirth and neonatal death compared. *Int J Epidemiol* 1991;20:173-9.
3. Kohler L. Infant mortality: the Swedish experience. *Annu Rev Public Health* 1991;12:177-93.
4. Naeye RL. Maternal age, obstetric complications, and the outcome of pregnancy. *Obstet Gynecol* 1983;61:210-6.
5. Cnattingius S, Haglund B, Meirik O. Cigarette smoking as risk factor for late fetal and early neonatal death. *BMJ* 1988;297:258-61.
6. Raymond EG, Cnattingius S, Kiely JL. Effects of maternal age, parity, and smoking on the risk of stillbirth. *BJOG* 1994;101:301-6.
7. Little RE, Weinberg CR. Risk factors for antepartum and intrapartum stillbirth. *Am J Epidemiol* 1993;137:1177-89.
8. Cnattingius S, Bergstrom R, Lipworth L, Kramer MS. Prepregnancy weight and the risk of adverse pregnancy outcomes. *N Engl J Med* 1998;338:147-52.
9. Taffel SM. Maternal weight gain and the outcome of pregnancy. *Vital Health Stat* 21 1986;44:1-25.
10. Rydhström H, Tyden T, Herbst A, Ljungblad U, Walles B. No relation between maternal weight gain and stillbirth. *Acta Obstet Gynecol Scand* 1994;73:779-81.
11. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960-1994. *Int J Obes Relat Metab Disord* 1998;22:39-47.
12. Kuskowska-Wolk A, Bergström R. Trends in body mass index and prevalence of obesity in Swedish women 1980-89. *J Epidemiol Community Health* 1993;47:195-9.
13. Cnattingius S, Ericson A, Gunnarskog J, Källén B. A quality study of a medical birth registry. *Scand J Soc Med* 1990;18:143-8.
14. Swedish version of international classification of diseases, 9th revision. Stockholm: Liber/Allmänna Förlaget; 1986.
15. National High Blood Pressure Education Program Working Group Report on High Blood Pressure in Pregnancy. *Am J Obstet Gynecol* 1990;163:1691-712.
16. Swedish socioeconomic classification: reports on statistical coordination. Stockholm: Statistics Sweden; 1995.
17. Brookmeyer R, Liang KY, Linet M. Matched case-control designs and overmatched analyses. *Am J Epidemiol* 1986;124:693-701.
18. Stone JL, Lockwood CJ, Berkowitz GS, Alvarez M, Lapinski R, Berkowitz RL. Risk factors for severe preeclampsia. *Obstet Gynecol* 1994;83:357-61.
19. Institute of Medicine Subcommittee on Nutritional Status and Weight Gain during Pregnancy. *Nutrition during pregnancy. Part I: weight gain.* Washington: National Academy Press; 1990.
20. Abrams B, Carmichael S, Selvin S. Factors associated with the pattern of maternal weight gain during pregnancy. *Obstet Gynecol* 1995;86:170-6.
21. Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. *Bull World Health Organ* 1987;65:663-737.
22. Stein ZA, Susser M. Intrauterine growth retardation: epidemiological issues and public health significance. *Semin Perinatol* 1984;8:5-14.
23. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991-1998. *JAMA* 1999;282:1519-22.
24. Manson JE, Willett WC, Stampfer MJ, Colditz GA, Hunter DJ, Hankinson SE, et al. Body weight and mortality among women. *N Engl J Med* 1995;333:677-85.