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Pre-pregnancy weight and the risk of stillbirth and neonatal death

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Objective To evaluate the association between maternal pre-pregnancy body mass index (BMI) and the risk of stillbirth and neonatal death and to study the causes of death among the children.

Design Cohort study of pregnant women receiving routine antenatal care in Aarhus, Denmark.

Setting Aarhus University Hospital, Denmark, 1989–1996.

Population A total of 24,505 singleton pregnancies (112 stillbirths, 75 neonatal deaths) were included in the analyses.

Methods Information on maternal pre-pregnancy weight, height, lifestyle factors and obstetric risk factors were obtained from self-administered questionnaires and hospital files. We classified the population according to pre-pregnancy BMI as underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25–29.9 kg/m^2) and obese (BMI 30.0 kg/m^2 or more).

Main outcome measures Stillbirth and neonatal death and causes of death.

Results Maternal obesity was associated with a more than doubled risk of stillbirth (odds ratio = 2.8, 95% confidence interval [CI]: 1.5–5.3) and neonatal death (odds ratio = 2.6, 95% CI: 1.2–5.8) compared with women of normal weight. No statistically significantly increased risk of stillbirth or neonatal death was found among underweight or overweight women. Adjustment for maternal cigarette smoking, alcohol and caffeine intake, maternal age, height, parity, gender of the child, years of schooling, working status and cohabitation with partner did not change the conclusions, nor did exclusion of women with hypertensive disorders or diabetes mellitus. No single cause of death explained the higher mortality in children of obese women, but more stillbirths were caused by unexplained intrauterine death and fetoplacental dysfunction among obese women compared with normal weight women.

Conclusion Maternal obesity more than doubled the risk of stillbirth and neonatal death in our study. The present and other studies linking maternal obesity to an increased risk of severe adverse pregnancy outcomes emphasise the need for public interventions to prevent obesity in young women.

INTRODUCTION

Obesity is a major public health problem in developed countries.[1,2] In pregnancy, maternal obesity is associated with increased fetal growth and a higher frequency of pregnancy complications such as hypertensive disorders, gestational diabetes and an increased need of operative delivery.[3,4] Few studies have evaluated the association between maternal pre-pregnancy weight and the risk of stillbirth and neonatal death, but results indicate an increased risk of stillbirth and early neonatal death in children of obese women.[5–7] The potential mediating factors and biological mechanisms behind these findings are still speculative, and studies of causes of death among the children are warranted.

We aimed to evaluate the association between maternal pre-pregnancy weight and the risk of stillbirth and neonatal death in a large cohort study, taking into account a number of potential confounding factors. A clinical–pathological classification of all deaths was used in the search for potential causal mechanisms.

METHODS

All women who booked for delivery at the Department of Obstetrics and Gynaecology, Aarhus University Hospital, Denmark, from 1989 to 1996, were invited to participate in the Aarhus Birth Cohort Study. The women received two questionnaires by mail, at approximately 12–16 weeks of

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Table 1. Stillbirths and neonatal deaths according to maternal characteristics in Århus, Denmark, 1989–1996.

	No. of births	Stillbirths		Neonatal deaths	
	n	*n*	*n*/1000 births	*n*	*n*/1000 births
Body mass index					
<18.5	1812	10	5.5	7	3.9
18.5–24.9	19,169	79	4.1	54	2.8
25.0–29.9	2573	12	4.7	7	2.7
30.0+	951	11	11.6	7	7.4
Age					
15–24 years	3706	13	3.5	12	3.2
25–29 years	9990	46	4.6	30	3.0
30–34 years	7646	33	4.3	22	2.9
35+ years	3163	20	6.3	11	3.5
Parity					
Primiparous	12,241	61	5.0	43	3.5
Multiparous	12,227	51	4.2	32	2.6
Missing	37	0	0.0	0	0.0
Smoking					
0 cigarettes/day	17,031	63	3.7	46	2.7
1 to 9 cigarettes/day	3114	17	5.5	16	5.2
10+ cigarettes/day	3744	31	8.3	11	3.0
Missing	616	1	1.6	2	3.3
Alcohol intake					
<1 drink/week	16,193	65	4.0	48	3.0
1–4 drinks/week	7226	39	5.4	20	2.8
5+ drinks/week	546	7	12.8	3	5.6
Missing	540	1	1.9	4	7.4
Caffeine intake					
<400 mg/day	12,501	43	3.4	38	3.1
400+ mg/day	5445	36	6.6	14	2.6
Missing	6559	33	5.0	23	3.5
Living with partner					
Yes	19,801	92	4.6	60	3.0
No	872	3	3.4	3	3.5
Missing	3832	17	4.4	12	3.1
Years of schooling					
7–10	7272	30	4.1	21	2.9
11+	10,340	44	4.3	31	3.0
Missing	6893	38	5.5	23	3.4
Working status					
Working	11,716	51	4.4	32	2.7
Unemployed	3736	19	5.1	17	4.6
Student	1863	7	3.8	1	0.5
Missing	7190	35	4.9	25	3.5
Gender of the child					
Male	12,617	67	5.3	41	3.3
Female	11,886	44	3.7	34	2.9
Missing	2	1	500.0	0	0.0
Diabetes mellitus					
No	22,008	92	4.2	62	2.8
Yes	171	3	17.5	1	6.0
Missing	2326	17	7.3	12	5.2
Hypertensive disorder					
No	20,368	85	4.2	56	2.8
Yes	1123	10	8.9	6	5.4
Missing	3014	17	5.6	13	4.3

gestation. The first questionnaire provided information on medical and obstetric history, pre-pregnancy weight and height, smoking habits and alcohol intake during pregnancy. The second, meant for research purposes only, provided information on cohabitation with partner, educational level, working status, caffeine intake during pregnancy and maternal chronic diseases.

The study population included Danish-speaking women with singleton pregnancies who did not have an induced abortion and who had completed the first questionnaire ($N = 25{,}788$). Of all women invited to participate in the Aarhus Birth Cohort study, 95% completed the first questionnaire. Approximately 5% of the population were born outside Denmark and a smaller proportion of these were non-Danish-speaking. We excluded pregnancies that were included in the cohort after birth had occurred ($n = 7$) and pregnancies ending with a miscarriage, defined as delivery of a dead fetus before 28 completed weeks of gestation ($n = 345$). Further exclusion of 931 women with missing information on pre-pregnancy weight or height resulted in a final population of 24,505 pregnancies (112 stillbirths, 75 neonatal deaths). All live births were included in the analysis, irrespective of gestational age at the time of delivery. In the analysis of neonatal death, stillbirths were excluded from the denominator.

Stillbirth was defined as delivery of a dead fetus at 28 completed weeks of gestation or later in pregnancy, and neonatal death as death of a liveborn child on days 1–28 following delivery. Information on stillbirth, including causes of death, was obtained from the cohort and from the Danish Medical Birth Register through record linkage using the mother's personal identification number. We chose the limit of 28 completed weeks as this was the limit of stillbirth *versus* abortion according to the Danish legislation at the time data were collected. Therefore, data on fetal deaths before 28 completed weeks of gestation were obtainable only from a different register (Danish National Patient Register). Unlike the Danish Medical Birth register, this register does not include information about causes of death, and the validity of data on miscarriages is dubious. Mixing information from the two registries would therefore make analyses of causes of death in stillborn children difficult. Information on neonatal death was obtained from the national Registry of Causes of Death and cross-checked

with information from the national Civil Registration System and the medical records.

The women's own information on height (cm) and recall of pre-pregnancy weight (kg) was used to calculate their body mass index (BMI = weight [kg]/height [m^2]). We classified the population according to pre-pregnancy BMI as underweight (below 18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2) and obese (30.0 kg/m^2 or more). These levels are in accordance with the World Health Organisation's recommendations.[8] Alcohol consumption during pregnancy was recorded as the number of drinks per week, one drink containing 12 g of alcohol equivalent of one beer (33 cL), one glass of wine or 4 cL of spirits. We calculated caffeine intake from the reported daily consumption of coffee, tea, drinking chocolate and cola.[9] Maternal alcohol consumption, cigarette smoking, caffeine intake, years of school, working status and cohabitation with partner were categorised as reported in Table 1.

We obtained information on complications during pregnancy from the birth registration form filled in by the attending midwife immediately after delivery and subsequently manually checked by reviewing all prospectively collected information in the woman's hospital and delivery record. The women were categorised as having hypertensive disorder if blood pressure of 140/90 mmHg or more was recorded during pregnancy. Under the heading diabetes mellitus, we included both non-insulin- and insulin-dependent diabetes mellitus present before pregnancy as well as gestational diabetes mellitus. From the research questionnaire, we obtained information on various maternal chronic diseases present before pregnancy.

Causes of death were classified according to the classification suggested by Andersen *et al.*[10] based on categorisations suggested by Cole *et al.*[11] and Hey *et al.*[12] The classification identifies the factor that probably initiated the chain of events leading to death.[10] It was proposed by the authors as a more simple clinical alternative to the International Classification of Diseases. The classification includes nine main categories and illustrates fetal conditions, happenings in pregnancy, the course of delivery and in the neonatal period. For deaths in our cohort that could not be classified unambiguously on the basis of the register data, the medical records and autopsy reports were consulted before the final classification. Maternal diabetes mellitus and hypertensive disorder were furthermore studied separately as possible links on a causal pathway.

The association between pre-pregnancy BMI and mortality is presented as odds ratios (OR) with 95% confidence intervals (CI). Effect modification was evaluated by stratified analyses, and potential confounding by logistic regression analyses. The following variables, selected because of their possible or established association with the outcome, were evaluated as potential confounders or effect modifiers: maternal age, height, parity, years of schooling, working status, smoking, alcohol and caffeine intake during pregnancy, gender of the child and cohabitation with partner.[13–16] We intended to perform logistic regression in two ways using (a) a model in which we included all variables changing the risk estimate by more than 10%,[17] and (b) a model in which we included all the pre-selected potential confounders mentioned above. Women with missing values were included in a separate category as shown in Table 1.

The study was approved by the regional Ethics Commitee, the Danish Data Protection Agency and the Danish National Board of Health.

RESULTS

Seventy-eight percent of the women in our study population were classified as being of normal weight, 7.4% as underweight, 10.5% as overweight and 3.9% as obese. The overall rate of stillbirth was 4.6 per 1000 deliveries, and of neonatal death 3.1 per 1000 live births. The proportions of stillbirths and neonatal deaths according to maternal characteristics and gender of the child are presented in Table 1.

Compared with women of normal weight, the relative risk of stillbirth and neonatal death in children of obese women more than doubled in the univariate analyses

Table 2. Stillbirth and neonatal death in relation to maternal pre-pregnancy BMI in Århus, Denmark, 1989–1996.

Maternal BMI	No. of births	Stillbirth					Neonatal death				
		No. of deaths	Unadjusted		Adjusted*		No. of deaths	Unadjusted		Adjusted*	
			OR	95% CI	OR	95% CI		OR	95% CI	OR	95% CI
<18.5	1812	10	1.3	0.7–2.6	1.3	0.7–2.6	7	1.4	0.6–3.0	1.3	0.5–2.9
18.5–24.9	19,169	79	1.0	–	1.0	–	54	1.0	–	1.0	–
25.0–29.9	2573	12	1.1	0.6–2.1	1.2	0.6–2.2	7	1.0	0.4–2.1	1.0	0.4–2.2
30.0+	951	11	2.8	1.5–5.3	3.1	1.6–5.9	7	2.6	1.2–5.8	2.7	1.2–6.1

* Odds ratio adjusted for maternal age, height, parity, smoking, years of schooling, working status, alcohol and caffeine intake, cohabitation with partner and gender of the child.

Table 3. Neonatal death in relation to maternal pre-pregnancy BMI in primiparous and multiparous women in Århus, Denmark, 1989–1996.

Maternal BMI	Primiparous women				Multiparous women			
	No. of births	No. of deaths	OR	95% CI	No. of births	No. of deaths	OR	95% CI
<18.5	924	6	2.4	1.0–5.8	878	1	0.4	0.1–2.8
18.5–24.9	9874	27	1.0	–	9178	27	1.0	–
25.0–29.9	1202	4	1.2	0.4–3.5	1351	3	0.7	0.2–2.5
30.0+	405	6	5.5	2.3–13.4	530	1	0.6	0.1–4.7

(Table 2). We found a small and statistically insignificantly increased risk of stillbirth and neonatal death in underweight and overweight women (Table 2).

Compared with women of normal weight, obese women reported more often that they had no partner (5% *vs* 3%), no job (21% *vs* 14%), less than 10 years of schooling (45% *vs* 28%), smoked more than 10 cigarettes/day (21% *vs* 14%) and were multiparous (57% *vs* 49%). Furthermore, obese women less often reported an alcohol intake of more than five drinks per week (0.3% *vs* 2.4%).

In the multivariate analyses, inclusion of maternal cigarette smoking, alcohol and caffeine intake, maternal age, height, parity, gender of the child, years of schooling, working status and cohabitation with partner all revealed a less than 10% change of the risk estimates when included successively. Inclusion of all the mentioned variables in a logistic regression model had little impact on the point estimates of interest (Table 2).

Parity did not modify the risk of stillbirth in our data (data not presented). However, we found a tendency towards a difference in risk of neonatal death in primiparous and multiparous women (Table 3).

The proportion of women with diabetes and hypertensive disorder increased with increasing maternal BMI. Diabetes mellitus was diagnosed in 0.4% of the underweight and normal weight women, 1.4% of the overweight and 5.5% of the obese women. The proportion of women with hypertensive disorder increased from 2.5% among women who were underweight to 3.7% among women of normal weight, 8.5% among the overweight and 16.6% among obese women. Women with any of these two disorders were at increased risk of stillbirth and neonatal death (Table 1). However, exclusion of women with either of these disorders from the analyses did not change the conclusions nor did exclusion of women with self-reported chronic diseases including essential hypertension (data not shown).

No single cause of death explained the higher risk of stillbirth in children of obese women. However, higher proportions of stillbirths caused by unexplained intrauterine death and fetoplacental dysfunction were found in children of obese women compared with children of non-obese women (BMI < 30) (Table 4). No trends could be seen for causes of neonatal death (data not shown). No deaths in children of overweight or obese women were caused by maternal disorders such as diabetes mellitus and hypertensive disorders.

Stillbirth occurred among 11 children born by obese mothers. Two children were born preterm (18%), eight at term (73%) and one post term (9%). Non-obese mothers accounted for 101 stillborn children. Among these, 50 children were born preterm (50%), 49 at term (49%) and 2 were born post term (2%). The mean birthweight of the nine stillborn children born at term or post term by obese mothers was 3.168 kg (SD 0.710 kg). Liveborn children born at term or post term by obese mothers had a mean birthweight of 3.768 kg (SD 0.548 kg) (mean difference 0.600 kg, $P < 0.05$).

Table 4. Causes of stillbirth in children of women with different pre-pregnancy BMI in Århus, Denmark, 1989–1996. Listed as number of deaths (*n*) and number of deaths per 1000 deliveries (*n*/1000).

	Maternal BMI <18.5		Maternal BMI 18.5–24.9		Maternal BMI 25.0–29.9		Maternal BMI 30.0+	
	n	*n*/1000	*n*	*n*/1000	*n*	*n*/1000	*n*	*n*/1000
Congenital malformations	0	0.0	7	0.4	0	0.0	0	0.0
Unexplained intrauterine death	0	0.0	14	0.7	1	0.4	4	4.3
Fetoplacental dysfunction	2	1.1	27	1.4	5	2.0	5	5.4
Antepartum haemorrhage	5	2.8	12	0.6	3	1.2	0	0.0
Maternal disorders	1	0.6	8	0.4	0	0.0	0	0.0
Intrapartum complications	1	0.6	4	0.2	2	0.8	1	1.1
Infections	0	0.0	6	0.3	0	0.0	0	0.0
Other specific causes	0	0.0	1	0.1	1	0.4	1	1.1

DISCUSSION

In a large cohort study, we found that obese women had more than twice the risk of stillbirth and neonatal death than women of normal weight. These findings agree with those of other authors who have reported increased risk of stillbirth, early neonatal and perinatal death among children of obese women.[5–7,18] However, our data did not find that the leanest women had the lowest risk of adverse pregnancy outcome as suggested in some studies.[5,6] Compared with earlier studies, we used a lower limit of BMI to define underweight (18.5 kg/m^2 *vs* 20 kg/m^2). In our population, 26% of the women had a BMI below 20 kg/m^2. The slightly increased risk of adverse pregnancy outcome found among underweight women in our study disappeared if underweight was defined as BMI below 20 kg/m^2. Thus, the WHO definition of underweight may improve identification of the high risk underweight women.

Cnattingius *et al.*[5] found that maternal BMI influenced the risk of *early* neonatal death only in primiparous women. Supporting these findings, our study suggested that maternal BMI was associated with neonatal death only among primiparous women. The difference in risk of neonatal death in primiparous and multiparous women was, however, not statistically significant and the number of deaths in each category was low.

Data in this study were collected prospectively in a homogeneous population of Danish-speaking women. Information on maternal pre-pregnancy weight and height was available in 96% of the women who were eligible for the study. Calculation of maternal BMI was based on self-reported height and recall information of pre-pregnancy weight. Data were collected prospectively before the pregnancy outcome was known and at a time when pregnancy weight gain was low and the women were likely to remember their habitual weight. Any possible misclassification of exposure is therefore most likely unrelated to the outcome and would lead to under-estimation of the associations found in this study (bias towards the null hypothesis). The quality of self-reported weight and height has been evaluated in several studies. Women tend to underreport their weight, and the degree of underreporting increases with increasing body weight.[19,20] Such possible misclassification of women in a lower BMI class would again lead to under-estimation of the true risk associated with high maternal BMI. The collected information on stillbirth and neonatal death was cross-checked using different national registers, and all deaths were validated by reviewing the hospital records. Thus, misclassification of stillbirth and neonatal death is an unlikely explanation for our findings.

We have previously shown that smoking and alcohol intake during pregnancy is associated with an increased risk of stillbirth,[21,22] but adjusting for these factors did not substantially change our results. A Danish study from 1999 found no relation between maternal socio-economic status and the risk of stillbirth, while infant mortality was associated with maternal educational level.[23] In our study, adjusting for maternal years of schooling, working status and cohabitation with a partner did not change the conclusions.

Information on pregnancy weight gain was not available in the present study. In two studies from Sweden, maternal weight gain during pregnancy did not confound the association between BMI and stillbirth and/or early neonatal death.[5,7]

Some authors have found that diabetes and hypertensive disorders might partially explain the association between maternal BMI and the risk of adverse pregnancy outcome,[4,6] while others have not.[5] In our study, the increased risk of hypertensive disorder and diabetes in obese women did not explain the association.

Compared with stillbirths in non-obese women, stillbirths in obese women more often occurred at term or post term, and the cause of death was more often unexplained. It has been suggested that in unexplained stillbirths the children are often discretely small for gestational age.[24] We found that the mean birthweight of children of obese women who were born at term and post term were lower among stillborn children compared with live born children. This may, however, be biased by the fact that we do not know the date of death of the stillborn babies, but only the date of birth.

Clinical evaluation of fetal size is difficult especially in obese women. Ultrasound scan has improved the estimation significantly but the reference curves of fetal growth may improve if individual data such as maternal physical characteristics and smoking habits are taken into account.[25]

Obesity is known to be associated with disturbances in lipid metabolism and in the endocrine system.[26,27] Hyperlipidaemia may, through a reduction in prostacycline secretion and an elevation of thromboxane production, increase the risk of placental thrombosis and decrease placental perfusion.[28] This risk may be increased even further in individuals with combined hyperlipidaemia and insulin resistance, in whom fibrinolytic activity is known to be markedly decreased.[29] The increased risk of stillbirth caused by fetoplacental dysfunction, found in obese women in this study, may be explained by impaired placental blood flow.

CONCLUSION

The prevalence of obesity is increasing in many countries in the Western world. Our data suggest that obesity is associated with a marked increased risk of stillbirth and neonatal deaths emphasising the need for public interventions to prevent obesity in young women. Prevention of antenatal stillbirth in obese women may be improved by lower threshold of referral of obese women to examination by an obstetric specialist, increased use of growth estimation by ultrasound scan and construction of customised growth charts.

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