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ORIGINAL ARTICLE

Pre-pregnancy body mass index (BMI) and macrosomia in a Canadian birth cohort

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Abstract

Objective: To compare demographic characteristics and maternal, fetal, neonatal, and pregnancy outcomes of term macrosomic infants of obese and non-obese mothers.
Methods: A sample of 1996 singleton, term deliveries was drawn from the All Our Babies Cohort, a prospective, community-based pregnancy cohort. Maternal self-reported socio-demographic and anthropometric information was linked to the clinical data on pregnancy and birth events abstracted from electronic health records. Demographic, obstetrical characteristics and maternal, fetal, neonatal, and pregnancy outcomes of macrosomic infants in obese, overweight, and normal weight women were compared. Multinomial regression analysis assessed the risk factors of macrosomia in primiparous and multiparous women stratified by maternal pre-pregnancy BMI, controlling for confounding variables.
Results: Macrosomia affected 10% of pregnancies in the study. Mothers whose infants were macrosomic were more likely to be Caucasian, obese, have had previous deliveries, undergo induction of labour and delivery by emergency C-section, particularly for labour abnormalities. Macrosomic infants were more likely to be delivered postdates, have meconium stained liquor and require resuscitation at birth. There were no significant differences in birth and neonatal outcomes of macrosomic pregnancies between obese, overweight and normal weight women. Pre-pregnancy BMI and gestational age at delivery were risk factors for macrosomia in all women. Ethnicity and history of delivery of a macrosomic infant were additional independent risk factors in multiparas.
Conclusions: Obesity in pregnancy increases the risk of delivery of a macrosomic infant in both primiparous and multiparous women. The maternal, fetal and neonatal outcomes of macrosomic pregnancies are similar in obese and normal weight women.

Keywords

Macrosomia, pregnancy, pre-pregnancy BMI, obesity, overweight

History

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Introduction

Birth weight is an important outcome of interest in obstetrics and perinatology as a proxy to evaluate intrauterine growth. The term fetal macrosomia is defined either as birth weight beyond 4000 g, regardless of gestational age (GA) or as birth weight greater than 90th percentile for GA and demographics (race, sex). Macrosomia represents a challenge in obstetrics; excessive fetal growth has major adverse impacts on maternal and perinatal morbidity and mortality [1–4]. At birth, macrosomia is associated with increased rates of shoulder dystocia, skeletal and brachial plexus injuries, hypoglycemia, difficulties with breastfeeding and fetal death [5–7]. Evidence supports that intrauterine growth continues to influence growth and development during childhood and adolescence, and can potentially influence childhood obesity [8].

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The prenatal diagnosis of macrosomia is imprecise, ultrasound measurements are not reliable predictors of actual fetal weight [9]. Moreover, in spite of numerous morbidities associated with the macrosomic birth, no standardized clinical interventions for the treatment of suspected macrosomia are available to date [10].

The underlying mechanisms of fetal macrosomia are not well understood. Antenatal risk factors reportedly predict macrosomia at birth. For instance, maternal demographics and anthropometrics, general health, genetic and environmental factors may alter the intrauterine milieu resulting in atypical intrauterine growth [11]. However, no combination of these factors has been found to predict macrosomia accurately enough to be used clinically. In addition, most macrosomic infants do not have any identifiable risk factors and much of the variation in birth weight remains unexplained. Maternal obesity and excessive gestational weight gain have been correlated with abnormal fetal growth as estimated by birth weight [1,12]. Nevertheless, macrosomic fetuses are also born to women of normal pre-pregnancy body weight, suggesting that other factors may modulate the intrauterine environment,

affecting fetal growth. Multiparity and grand multiparity increase the risk of macrosomia by 5–10 fold and a history of macrosomia is a risk factor for delivery of a macrosomic baby in a subsequent pregnancy [13]. Preexisting and gestational diabetes in the index pregnancy are risk factors for macrosomia [11]. However, the extent to which these risk factors are associated with macrosomia in women with body weight across the BMI spectrum is not well understood. There is also limited information on the outcomes of macrosomic pregnancies in women from different BMI categories, normal weight, overweight or obese. This study aimed to investigate the differences, if any, in maternal and perinatal outcomes of macrosomic pregnancies among different pre-pregnancy BMI categories. Using information from a community-based, prospective pregnancy cohort, we also explored the risk factors for macrosomia in primiparous and multiparous women, in different pre-pregnancy BMI categories.

Methods

Study population

The data for this study was derived from the All Our Babies Cohort (AOB), a prospective community-based pregnancy cohort from Calgary, Alberta, Canada ($n = 3388$) [14]. Details about the recruitment, eligibility and data collection for the cohort are provided elsewhere [14]. In brief, women were identified in early pregnancy (<24 weeks gestation) and invited to participate if they were eligible for prenatal care in primary care offices in the Calgary area, were 18 years or older and able to complete a questionnaire in English [14,15]. Data was collected between May 2008 and December 2010. Women completed three questionnaires: in early pregnancy (<25 weeks gestation); late pregnancy (32–36 weeks gestation) and in postpartum (four months after delivery). Domains of data collection included demographics, pregnancy and health history, maternal lifestyle, health care utilization, events in pregnancy and at delivery, and breastfeeding. Questionnaire data were linked via unique identifiers (i.e. provincial health care number) to provincial electronic health records for labour and delivery that contain additional details on pregnancy complications and birth outcomes not captured by the surveys.

For the current study, the following inclusion criteria were used: single gestation, cephalic presentation, gestational age at delivery >37 weeks, pre-pregnancy BMI >18.5 kg/m^2, completion of all three questionnaires, and successful linkage between survey data and the electronic medical records from labor and delivery.

Statistical analysis and variables definitions

Macrosomia was defined in this study as birth weight ≥4000 g regardless of gestational age at delivery. Maternal pre-pregnancy body mass index (BMI) was calculated as self-reported weight prior to pregnancy (kg) divided by self-reported height (m) squared. Participants were categorized based on their pre-pregnancy BMI in: normal weight (BMI 18.50–24.99 kg/m^2), overweight (BMI 25.00–29.99 kg/m^2) and obese (BMI > 30.00 kg/m^2) [16,17]. Pregnancy complications (pregnancy-induced hypertension, preeclampsia, gestational diabetes) were studied as both composite and individual outcomes.

The exposure for this study was the maternal pre-pregnancy BMI (normal weight, overweight and obese). The outcomes of interest were pregnancy complications (pregnancy induced hypertension, preeclampsia, gestational diabetes (separate and combined), type of labour (induced versus spontaneous), mode of delivery (vaginal versus cesarean) and perinatal outcomes (Apgar score, resuscitation at birth, presence of meconium, NICU admission, length of hospital stay).

Descriptive statistics were produced for participant characteristics and outcome variables. Continuous data were expressed as mean ± standard deviation (SD) and median (range). Categorical data were summarized as frequency distributions.

Univariate analyses measured associations between socio-demographic and obstetrical characteristics and perinatal outcomes of macrosomic and normosomic pregnancies, stratified by maternal pre-pregnancy BMI, using chi-square and Fisher exact tests for dichotomous variables and Student *t*-test and analysis of variance (ANOVA) for continuous variables. Bivariate associations between maternal and infant characteristics were assessed to identify variables of importance for logistic regression modelling and potential confounders. Multivariable logistic regression models were then fitted to the data using a hierarchical model strategy which introduced a block of demographic variables [maternal age (≤34 years old, >35 years old), ethnicity (Caucasian, non-Caucasian), education (high school or less, some or completed post-secondary), household income (<$60 000, ≥$60 000)], followed by a block of obstetrical variables [parity (primiparas (no previous deliveries), multiparas (at least one previous delivery)), history of macrosomic birth (yes/no), gestational age at delivery (37–38 weeks, 39–40 weeks, 41–42 weeks), pre-exiting diabetes mellitus (yes/no) and gestational diabetes (yes/no)]. All models were conducted for each BMI category. Any variables in the model that were significant at an α level of 5% were kept in the model and identified as significant risk factors for macrosomia within the respective BMI category. Odds ratios and 95% confidence intervals were calculated for final models, which included only significant predictor variables for the outcome of macrosomia. All statistical analyses were performed using the SPSS for Windows package, versions 20 (IBM SPSS, Chicago, IL).

Ethical approval for the study was obtained from the Conjoint Health Research Ethics Board at the University of Calgary. Written informed consent was obtained from all study participants at the time of recruitment.

Results

Among 1996 term, singleton pregnancies included in this study, 198 (approximately 10%) resulted in macrosomic births. The mean birth weight of macrosomic infants was 4225.8 g, 21% greater than that of normosoms (mean = 3329.4 g).

Table 1 shows the maternal characteristics of macrosomic and normosomic infants. The two groups of women differed in several socio-demographic and obstetrical features.

Table 1. Socio-demographic and obstetrical characteristics of mothers of macrosom and normosom infants. .

Characteristics	Mothers of normosoms ($n = 1798$)	Mothers of macrosoms ($n = 198$)	p values
Socio-demographic			
Maternal age			
Mean ± SD; range (years)	31.0 ± 4.4; 19–43	31.9 ± 4.3; 20–43	
<35 years old	1390 (78.6)	149 (75.6)	0.342
≥35 years old	379 (21.4)	48 (24.4)	
Ethnicity *n* (%)			
White/Caucasian	1424 (79.4)	178 (89.9)	<0.001*
Other	370 (20.6)	20 (10.1)	
Time in Canada *n* (%)			
Born in Canada/lived ≥5 years	1622 (90.7)	186 (94.4)	0.080
Lived in Canada 5 years	167 (9.3)	11 (5.6)	
Education *n* (%)			
High-school or less	178 (9.9)	12 (6.1)	0.079
Some or completed post-secondary	1616 (90.1)	186 (93.9)	
Household income *n* (%)			
$39 999 or less	125 (7.2)	14 (7.3)	0.104
$40 000–$79 999	366 (21.0)	28 (14.5)	
$80 000 or more	1255 (71.9)	151 (78.2)	
Marital status *n* (%)			
Married or common law	1713 (95.4)	188 (94.9)	0.759
Single	82 (4.6)	10 (5.1)	
Maternal height (mean ± SD; range) (cm)	165.5 ± 6.7; 145.0–195.6)	169.3 ± 6.7; 152.4–187.9	0.738
Maternal pre-pregnancy weight (mean ± SD; range) (kg)	66.4 ± 13.4; 42.7–150.7	77.4 ± 16.3; 47.7–140.4	<0.001*
Maternal pre-pregnancy BMI			
Normal weight (BMI 18.5–24.9 kg/m^2)	1206 (67.1)	107 (54.0)	0.001*
Overweight (BMI 25.0–29.9 kg/m^2)	412 (22.9)	60 (30.3)	
Obese (BMI ≥ 30 kg/m^2)	180 (10.0)	31 (15.7)	
Smoking during pregnancy			
Yes	98 (5.5)	4 (2.0)	0.037*
No	1700 (94.5)	194 (98.0)	
Preexisting maternal health conditions[†]			
Yes	191 (10.6)	25 (12.6)	0.389
No	1607 (89.4)	173 (87.4)	
Obstetrical			
Gravidity			
Median; range	2; 1–38	2; 1–7	0.045*
Primigravidas	710 (39.6)	61 (32.3)	
Multigravida	1081 (60.4)	131 (67.7)	
Parity			
Median; range	0; 0–22	1; 0–3	<0.001*
Primiparas	966 (53.7)	79 (39.9)	
Multiparas	832 (46.3)	119 (60.1)	
Fertility treatments			
Yes	114 (6.4)	11 (5.6)	0.669
No	1678 (93.6)	186 (94.4)	
Pregnancy complications			
Composite variable[‡]			
Yes	318 (17.7)	171 (86.4)	0.166
No	1480 (82.3)	27 (13.6)	
All hypertensive disorders			
Yes	145 (8.1)	12 (6.1)	0.403
No	1653 (91.9)	186 (93.9)	
Preeclampsia			
Yes	122 (6.8)	8 (4.0)	0.171
No	1676 (93.2)	190 (96.0)	
Gestational diabetes mellitus			
Yes	70 (3.9)	8 (4.0)	0.847
No	1728 (96.1)	190 (96.0)	
Chorioamnionitis			
Yes	28 (1.6)	2 (1.0)	0.902
No	1770 (98.4)	196 (99.0)	
Type of Labor onset			
Spontaneous	1226 (68.2)	121 (61.1)	0.044*
Induced	572 (31.8)	77 (38.9)	
Mode of delivery			
Spontaneous vaginal	1399 (78.0)	142 (71.7)	<0.001*
Emergency C-section	214 (11.9)	46 (23.2)	
Instrumental deliveries (vacuum or/and forceps)	181 (10.1)	10 (5.1)	
Obstetrical analgesia			

(*continued*)

Table 1. Continued

Characteristics	Mothers of normosoms ($n = 1798$)	Mothers of macrosoms ($n = 198$)	p values
Any type of pain management			
Yes	1397 (77.8)	162 (81.8)	0.197
No	398 (22.2)	36 (18.2)	
Epidural in labor			
Yes	1071 (59.6)	121 (61.1)	0.674
No	727 (40.4)	77 (38.9)	
Delivery care provider			
Midwife	57 (3.2)	11 (5.6)	0.004*
General practitioner	984 (54.7)	85 (42.9)	
Obstetrician	757 (42.1)	102 (51.5)	
Breastfeeding at discharge			
Yes	1729 (96.2)	184 (92.9)	0.031*
No	69 (3.8)	14 (7.1)	

*$p < 0.05$.

†Includes: diabetes mellitus, hypertension, heart diseases, chronic renal diseases, other chronic medical disorders.

‡Includes: pregnancy-induced hypertension, preeclampsia, eclampsia, abruptio placentae, gestational diabetes, PROM, placenta praevia.
May not add to the total of 1996 due to missing data.

Mothers of macrosomic infants were more likely to be Caucasian, have higher incomes and to be overweight or obese prior to pregnancy. Age, income, education and marital status did not differ between mothers of macrosomic and mothers of normosomic infants. From 102 women in the sample who smoked during pregnancy, 98 were mothers to normosomic infants. We were not able to assess alcohol and recreational drug use due to small sample sizes. Little over half (1045, approximately 52%) of the women in the study were primiparas, with the other half having at least one previous delivery. Among multiparas, 12.5% had macrosomic newborns whereas among primiparas only 7.5% had macrosoms. Sixty percent of the macrosoms were born to multiparous women. As expected, labour and delivery characteristics were different between the two groups of women. Mothers of macrosomic babies were more likely to have their labour induced. There were differences in indications for labour induction between mothers of macrosoms and those of normosoms. The most frequent indication for labour induction for macrosomic pregnancies were postdates pregnancy (16% versus 6.8% among normosoms). Maternal indications were the most common reasons for induction in the normosomic group (8.7%). The majority of babies were delivered by physicians (obstetrics specialists or general practitioners); however, the obstetricians were more likely to attend to macrosomic than normosomic deliveries (51.5% versus 42.1%). In both groups of babies, fewer than 6% were delivered by midwives. Only 92% of women with macrosomic infants were breastfeeding at discharge compared to 96% of normosoms.

Table 2 summarizes the newborn characteristics and the events surrounding macrosomic and normosomic births. Macrosoms were more likely to be male, delivered after 40 weeks of gestation, have meconium-stained amniotic fluid and require resuscitation at delivery. No differences were observed in Apgar scores, prevalence of NICU admissions or length of hospital stay between macrosoms and normosoms. The proportion of newborns who required medical care after discharge was similar between the groups.

Table 3 summarizes the demographic, clinical, and obstetrical characteristics, and neonatal outcomes of macrosomic births stratified by maternal pre-pregnancy BMI. Of the 198 macrosoms, slightly more than half were born to normal weight women (54.4%), with the other half divided between overweight and obese women (30% and 15.6%, respectively). There were few differences in maternal socio-demographic characteristics between mothers of macrosoms: obese mothers were more likely to be Caucasian ($p = 0.030$), have diabetes mellitus during their reproductive years ($p = 0.001$), and to develop pregnancy-induced hypertension ($p = 0.002$) and preeclampsia ($p = 0.001$) in the current pregnancy as compared to normal-weight mothers. No differences in newborn gender, Apgar scores, resuscitation at birth, and length of hospital stay were observed between macrosoms of obese, overweight and normal weight mothers. However, macrosoms of women with normal BMI were more likely to be admitted to NICU (10% versus 3.2%; $p = 0.02$).

The multivariate regression models are presented in Supplementary Table 1. When the risk of macrosomia was modelled in all women, with pre-pregnancy BMI and gestational age included as continuous variables, we found that ethnicity, education, body weight prior to pregnancy, parity and gestational age at delivery were independently associated with fetal macrosomia. In this model, history of delivering of a macrosomic infant was the strongest predictor of macrosomia in the current pregnancy.

In all women, when gestational age at delivery was included in the model as categorical variable, gestational age >40 weeks (postdates) doubled the odds of macrosomia (adjusted OR 2.1, 95% CI 1.4–2.9). A direct relationship was observed between maternal BMI prior to pregnancy and the risk of fetal macrosomia when pre-pregnancy BMI was included as categorical variable in the model; a BMI of 25.0–29.9 kg/m^2 increased the risk of delivery of a macrosomic infant by 60%, while a BMI $\geq$30 kg/m^2 increased the risk by 90% (data not shown in the tables).

The risk of macrosomia was further modelled separately in primiparas and multiparas. In primiparous women, risk factors for macrosomia were pre-pregnancy BMI and gestational age at delivery, whereas the risk factors in multiparous women included pre-pregnancy BMI, gestational age at delivery, ethnicity and history of delivery of a macrosomic infant.

Table 2. Characteristics of macrosomic and normosomic newborns.

Characteristics	Normosoms($N = 1798$)	Macrosoms($N = 198$)	p values	OR; 95% CI
Birth weight (g)	3329.4 ± 371.3	4225.8 ± 216.1	<0.001*	
Gestational age at delivery (weeks) (mean ± SD)	39.2 ± 1.1	39.9 ± 1.0		
37–38 weeks	454 (25.3)	24 (12.1)	<0.001*	0.5; 0.3–0.8*
39–40 weeks	1076 (59.8)	115 (58.1)		1.00
>40 weeks	268 (14.9)	59 (29.8)		2.0; 1.5–2.9*
Neonatal gender				
Male	921 (51.2)	117 (59.1)	0.035*	1.4; 1.0–1.8*
Female	877 (48.8)	81 (40.9)		1.0
Apgar score at 5 min				
≥7	1770 (98.4)	197 (99.5)	0.240	0.3; 0.04–2.4
<7	28 (1.6)	1 (0.5)		1.0
Congenital anomalies				
Yes	135 (7.5)	18 (9.1)	0.427	1.2; 0.7–2.0
No	1663 (92.5)	180 (90.9)		1.0
Resuscitation at birth				
Yes	807 (44.9)	106 (53.5)	0.020*	1.4; 1.0–1.9*
No	991 (55.1)	92 (46.5)		1.0
Meconium stained amniotic fluid				
Yes	348 (19.4)	51 (25.8)	0.033*	1.4; 1.0–2.0*
No	1450 (80.6)	147 (74.2)		1.0
Admission to NICU				
Yes	106 (5.9)	12 (6.1)	0.925	1.0; 05–1.9
No	1692 (94.1)	186 (93.9)		1.0
Length of hospital stay				
>24 h	1057 (59.4)	122 (62.6)	0.395	1.1; 0.8–1.5
≤24 h	722 (40.6)	73 (37.4)		1.0
Infant visits to emergency†				
Yes	300 (16.7)	35 (17.7)	0.723	1.0; 0.7–1.5
No	1498 (83.3)	163 (82.3)		1.0
Infant hospitalized overnight†				
Yes	94 (5.2)	10 (5.1)	0.915	0.9; 0.5–1.8
No	1704 (94.8)	188 (94.9)		1.0

*$p < 0.05$.

†Refers to infant use of medical services after discharge home from labour and delivery ward.
May not add to the total of 1996 due to missing.

Discussions

Macrosomia is reportedly associated with increased neonatal and maternal morbidity, although it is not clear if difference exists in these risks between normal weight and obese women. In this study, maternal, fetal, neonatal and pregnancy outcomes of macrosomic infants of obese mothers were compared with those whose mothers were non-obese. A major finding of this study is that there was no severe intrapartum or postpartum morbidity in macrosomic infants of overweight and obese mothers as compared to normal weight mothers. That is, birth of macrosomic infant poses the same risks during labor and at delivery, irrespective of maternal body weight prior to pregnancy.

Intrapartum management of a suspected macrosomic fetus confronts the obstetrician with the challenge of tailoring the optimal management to each patient due to potentially unpreventable complications for mother and infant [18–22]. Maternal obesity is associated with increased risk of pregnancy complications and obstetrical interventions at birth and a suspected macrosomia could potentially escalate these risks. Our study demonstrates that, in a population-based sample of maternity patients, delivery of an infant with birth weight >4000 g was associated with an increased risk of perinatal complications and obstetrical interventions at birth. However, there was a similar likelihood of labour induction and obstetrical intervention at birth regardless of pre-pregnancy BMI. Also, there were no significant differences in the newborn characteristics, gestational age at delivery and wellbeing of the fetus at delivery according to maternal pre-pregnancy BMI category. Although obese women were more likely to have macrosomic babies and large for date infants were more likely to be delivered by obstetrical interventions and require paediatric care at birth, the macrosomic pregnancies were associated with comparable obstetrical and perinatal risks in women with increased or normal body weight.

Maternal obesity has been associated with increased neonatal weight and adiposity [23]. The analysis confirms that the risk of delivery of an infant with birth weight >4000 g increases with increasing maternal BMI prior to conception. Obese women had twice the risk of delivery of a macrosom infant compared to women with normal BMI prior to pregnancy. These results align with other reports that have shown a 1.5–2.3 increase in the adjusted odds of delivering large-for-dates infants among obese women [21–23].

The 10% occurrence of macrosomia in our cohort was similar to the incidence reported by other studies and professional associations' reports (7–10%). Only a few studies, in more selective populations, reported either lower (6%) [18] or higher rates (up to 13.6%) [24]. Because half of the macrosoms in our study were born to mothers with normal pre-pregnancy weight we investigated the potential risk factors that can predict increased birth weight in our

Table 3. Prenatal characteristics and perinatal outcomes of macrosom infants stratified by maternal pre-pregnancy BMI.

Variable‡	Maternal pre-pregnancy BMI			*p* values
	Normal weight $n = 107$	Overweight $n = 60$	Obese $n = 31$	
Demographic and clinical characteristics				
Maternal age				
34 years or less	83 (77.6)	42 (71.2)	24 (77.4)	0.636
35 years or more	24 (22.4)	17 (28.8)	7 (22.6)	
Parity				
Primiparas	42 (39.3)	22 (36.7)	15 (48.4)	0.546
Multipara	65 (60.7)	38 (63.3)	16 (51.6)	
Maternal preexistent health conditions				
Composite variable‡				
No	100 (93.5)	52 (86.7)	21 (67.7)	0.001*
Yes	7 (6.5)	8 (13.3)	10 (32.3)	
Diabetes mellitus				
No	107 (100.0)	56 (93.3)	23 (74.2)	<0.001*
Yes	0 (0.0)	4 (6.7)	8 (25.8)	
Hypertension				
No	106 (99.1)	59 (98.3)	31 (100.0)	0.748
Yes	1 (0.9)	1 (1.7)	0 (0.0)	
Obstetrical characteristics				
Pregnancy complications				
Composite variable¶				
No	95 (88.8)	53 (88.3)	23 (74.2)	0.099
Yes	12 (11.2)	7 (11.7)	8 (25.8)	
Pregnancy-induced hypertension				
No	105 (98.1)	56 (93.3)	25 (80.6)	0.002*
Yes	2 (1.9)	4 (6.7)	6 (19.4)	
Preeclampsia				
No	106 (99.1)	58 (96.7)	26 (83.9)	0.001*
Yes	1 (0.9)	2 (3.3)	5 (16.1)	
Gestational diabetes mellitus				
No	103 (96.3)	58 (96.7)	29 (93.5)	0.753
Yes	4 (3.7)	2 (3.3)	2 (6.5)	
Type of labour				
Spontaneous onset of labour	67 (62.6)	38 (63.3)	16 (51.6)	0.496
Induction of labour	40 (37.4)	22 (36.7)	15 (48.4)	
Mode of delivery				
Spontaneous vaginal	78 (72.9)	45 (75.0)	19 (61.3)	0.437
Emergency C-section	24 (22.4)	11 (18.3)	11 (35.5)	
Instrumental deliveries (vacuum or/and forceps)	5 (4.7)	4 (6.7)	1 (3.2)	
Indications for operative deliveries				
Abnormal Labour	19 (54.3)	11 (55.0)	11 (68.7)	0.667
Fetal distress	13 (37.1)	9 (45.0)	4 (25.0)	
Maternal indications	3 (8.6)	0 (0.0)	1 (6.2)	
Fetal and neonatal outcomes				
Gestational age at delivery				
37–38 weeks	10 (9.3)	7 (11.7)	7 (22.6)	0.237
39–40 weeks	65 (60.7)	32 (53.3)	18 (58.1)	
>40 weeks	32 (29.9)	21 (35.0)	6 (19.4)	
Birth weight (g) (mean ± SD)	4218.5 ± 220.1	4221.2 ± 206.4	4260.1 ± 224.1	0.631
Newborn gender				
Female	41 (38.3)	26 (43.3)	14 (45.2)	0.714
Male	66 (61.7)	34 (56.7)	17 (54.8)	
Apgar score at 5 min				
≥7	106 (99.1)	60 (100.0)	31 (100.0)	0.652
<7	1 (0.9)	0 (0.0)	0 (0.0)	
Resuscitation				
No	48 (44.9)	31 (51.7)	13 (41.9)	0.601
Yes	59 (55.1)	29 (48.3)	18 (58.1)	
Meconium				
No	83 (77.6)	43 (71.7)	21 (67.7)	0.469
Yes	24 (22.4)	17 (28.3)	10 (32.3)	
NICU admission				
No	96 (89.7)	60 (100.0)	30 (96.8)	0.022*
Yes	11 (10.3)	0 (0.0)	1 (3.2)	
Length of hospital stay				
Less than 24 h	39 (36.8)	27 (46.6)	7 (22.6)	0.082
More than 24 h	67 (63.2)	31 (53.4)	24 (77.4)	

*$p < 0.05$.

†All variables presented as *n* (%) unless otherwise specified.

‡Preexistent health conditions composite variable includes: diabetes mellitus, hypertension, heart diseases, chronic renal diseases, other chronic medical disorders.

¶Pregnancy complication composite variable includes: pregnancy induced hypertensive, preeclampsia, eclampsia, abruption placentae, prolonged rupture of membranes, placenta praevia, and gestational diabetes.

population of term, singleton, low-risk pregnancies. Among women who go to term, the prevalence of either preexisting diabetes mellitus or gestational diabetes, did not distinguish between women who deliver a normosom from those who deliver a macrosom. It is possible that selection criteria for our sample that excluded preterm deliveries (category which may have included women with gestational/pre-existed diabetes associated with other complications indicating elective preterm delivery or women with diabetes and spontaneous onset of preterm labour) may have biased these findings towards no effect. However, delivery before 37 weeks gestation is less likely to result in macrosomic babies. Previous delivery of a large for gestational weight infant was a strong predictor of macrosomia in multiparas, lending support to the theory of genetic and constitutional factors as contributors to the likelihood of an oversized baby [11]. Although pre-pregnancy BMI was a predictor of macrosomia in both primiparas and multiparas, parity was not different between obese, overweight and normal weight women with macrosomic pregnancies.

Finally, as previously reported, we observed higher rates of induction of labor and delivery by emergency C-section in macrosomic pregnancies. The relationship between labour induction and the rates of C-section in macrosomia is still controversial. Recent reports suggest that induction of labor may double the risk of C-section without reducing the risk of shoulder dystocia or newborn morbidity [20,25,26]. On the other hand, a small randomized clinical trial showed similar C-section cesarean rates for shoulder dystocia, major labour complication of macrosomia in the induction group (19.4%) compared with the expectant management group (21.6%). In their studies on birth weight >4000 g, Siggelkow et al. [20] showed a C-section rate of 27.4%, similar to our measured rate of 23%, whereas Lim et al. [26] reported rates are as high as 43.9%. Several other studies report higher rates of C-section in macrosomic babies [5,19,27]. Most frequent indications for elective C-sections were suspected macrosomia in nulliparous women [26] and protracted labour [20,28]. Sonographic estimation of fetal weight prior to labour has been shown, however, to increase the rate of C-sections independent of actual birth weight [29,30].

Perinatal outcomes of macrosoms were poorer than those of the normosomic infants, with the macrosomic infants being more likely to require resuscitation at birth, although Apgar scores and NICU admissions were not significantly different between the two categories of newborns. The prevalence of adverse perinatal outcomes in macrosoms was similar across all maternal BMI categories, with the exception of admission to NICU, which was more prevalent in normal weight mothers, although the reason for such occurrence is not readily evident.

We acknowledge several limitations of our study. The relatively small sample of macrosoms when stratified by pre-pregnancy BMI category may have precluded significant differences in occurrence of rare events such as low Apgar scores or increased length of hospitalization. We had no information on the estimated fetal weight by ultrasounds; thus, we could not appreciate if suspected macrosomia contributed to the findings of our study. In addition, the macrosomia outcomes were evaluated in a pooled sample of different categories of obese women; due to small sample of severely obese women ($n = 31$) we were unable to investigate the outcomes separately by the obesity sub-categories as defined by World Health Organization and Institute of Medicine [31]. Another limitation of this study is reliance on self-reported body weight and height, which may have led to potential inaccuracies in BMI reporting, with possible underestimation of the true risk [32,33]. We have shown in previous publications a high level of agreement between maternal self-report on demographics, environmental, and obstetrical information and the corresponding medical records data [21,34]. However, the prospective collection of data from pregnancy, labour and delivery and the representativeness of our sample for the population of province of Alberta and Canada, are major strengths of our study, increasing the reliability of our findings. In addition, several lines of evidence, including systematic reviews support associations between excessive gestational weight gain and increased birth weight and fetal growth [35]. Some evidence also shows a possible additive interaction between BMI and pregnancy weight gain in influencing development of the gestational diabetes [36]. No data on weight gain during pregnancy was available to this study, thus we were unable to evaluate the possible contribution of weight gain as a predictor of macrosomia in our study.

In conclusion, our study demonstrates that maternal and perinatal outcomes are similar in macrosomic pregnancies of obese, overweight and normal weight women suggesting that the size of the fetus poses similar risks during parturition regardless of pre-pregnancy BMI. However, our findings support that macrosomic infants experience increased odds of adverse perinatal outcomes some of which may be directly attributable to fetal size. With rates of obesity in developed countries continue to rise, the incidence of macrosomia is expected to rise, along with the rates of specialized obstetrical care and interventions at birth. Identification of mothers at risk of macrosomia and targeted pre-conception interventions to reduce body weight among women with high BMI may mitigate the increase in macrosomia. Additionally, implementation of appropriate management plans for counselling, monitoring and management during pregnancy and delivery could reduce the incidence of adverse neonatal outcomes associated with macrosomic pregnancy. To further impact the rate of macrosomic pregnancies, specialized post-partum follow up and weight management prior to subsequent pregnancies may help to reduce the pre-pregnancy BMI of women at higher risk of repeat macrosomic pregnancies.

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Declaration of interest

Authors do not have conflicts of interest to declare.

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