Perinatal outcomes of maternal overweight and obesity in term infants: a population-based cohort study in Canada

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The objective of this study was to assess the impact of increased pre-pregnancy maternal body mass index (BMI) on perinatal outcomes in term, singleton pregnancies who received prenatal care in community-based practices. The sample of 1996 infants included in the study was drawn from the All Our Babies Study, a prospective pregnancy cohort from Calgary. Multivariable logistic regression explored the relationship between the main outcomes, infant birth weight, Apgar score, admission to neonatal intensive care (NICU) and newborn duration of hospitalization, and BMI prior to pregnancy. Approximately 10% of the infants were macrosoms, 1.5% had a low Apgar score (<7 at 5 min), 6% were admitted to intensive care and 96% were discharged within 48 h after delivery. Although the infants of overweight and obese women were more likely to have increased birth weight as compared to infants of normal weight women, there were no differences in Apgar score, admission to NICU, or length of postnatal hospital stay among groups. This study suggests that in otherwise healthy term, singleton pregnancies, obesity does not seem to increase the risk of severe fetal impairment, neonatal admission to intensive care or duration of postnatal hospitalization.

Obesity has become a worldwide epidemic and an important health concern due to increased risk of serious health consequences that encompass metabolic and cardiovascular complications1,2. Consistent with the trend observed in the general population, the rates of overweight and obesity in women of childbearing age are increasing rapidly. In Canada, over 10% of women of reproductive age are obese3,4. In USA, more than half of pregnant women are obese or overweight, and around 8% are morbidly obese5. Maternal overweight and obesity increase the risks of complications during pregnancy and delivery6–8 as well as neonatal and infant morbidity and mortality9–12. Obesity and morbid obesity in pregnancy has been linked to antepartum stillbirth, large-for-gestational-age (LGA), shoulder dystocia, meconium aspiration, fetal distress13 and 5 min Apgar score <414. Other perinatal problems associated with maternal obesity include congenital anomalies15,16, birth trauma, birth asphyxia, and neonatal hypoglycemia17 although the underlying mechanisms of these associations are still uncertain10.

While evidence suggests that maternal obesity is a risk factor for adverse labour and delivery outcomes18–20 and increased health care service utilization at birth, it is not clear to what extent maternal BMI prior to pregnancy influence neonatal health. Several studies report on adverse perinatal outcomes in severely obese mothers21,22 but few describe the impact of maternal obesity from the remainder of BMI classification categories on Apgar score, newborn admission to the intensive care or neonatal length of stay19. Furthermore, although fetal macrosomia (birth weight over 4,000 g) is recognized as a clinical problem in obstetrics, there are no specific recommendations for intrapartum care of these infants. In addition, most studies describe the perinatal outcomes in heterogeneous populations, including both preterm and term pregnancies21; however, the overall morbidity at birth may be different in obese women from otherwise healthy pregnancy as compared to women with additional risk factors. Taken together, this suggests that different populations, different classifications of obesity and probably
other confounding factors may impact on the commonly perceived high risk of adverse perinatal outcomes in obese women.

Therefore, this study aimed to determine the impact of maternal pre-pregnancy BMI on perinatal outcomes in a population of term, singleton, cephalic pregnancies who received prenatal care in community health care centers and obstetrical care in labour and at delivery in tertiary centers. The primary question to be answered was to determine the relationships between increased maternal body weight before pregnancy and fetal vitality and wellbeing at delivery defined as Apgar score, neonatal intensive care admission and length of hospital stay. This study also develops previous work regarding the influence of maternal BMI on fetal intrauterine growth.

Methods
The data for this study was drawn from the All Our Babies Study (AOB), a prospective community-based pregnancy cohort of approximately 3388 women born in Calgary, Alberta, Canada40. Women were enrolled in the AOB study from December 2008 to July 2010, at less than 24 weeks of gestation and completed three questionnaires at 24 and 32 weeks of gestation, and 4 months post-partum. Self-reported data on demographics, lifestyle, health care utilization, pregnancy history, and physical and mental health were collected and this information was linked to the obstetric electronic medical records from recruitment and delivery. Maternal pre-pregnancy BMI was defined as Apgar score, neonatal intensive care admission and length of hospital stay. This study also develops previous work regarding the influence of maternal BMI on fetal intrauterine growth.

Information about socio-demographic characteristics and length of hospital stay were obtained from self-reported questionnaires. The socio-demographic characteristics of the study population. Bivariate regression analyses test was used to examine the associations between different BMI groups and the socio-economic characteristics of the study population. Bivariate regression analyses and frequency distributions were used to summarize the categorical data. Chi-square significance. Odds ratios and 95% confidence intervals were presented for final models; a value of $p < 0.05$ was considered statistically significant. All statistical analyses were performed using the SPSS for Windows package, versions 20 (IBM SPSS, Chicago, IL).

Results
Population demographic and obstetrical characteristics. Table 1 summarizes the demographics of the study population. Of the 1996 participants included in the study, 1313 (65.8%) were normal weight, 427 (23.6%) were overweight and 211 (10.6%) were obese (the anthropometric measures presented in Table 1), from which 31 had BMI $\geq 40$ kg/m$^2$. The majority of women in the study were Caucasian (1602; 80.4%), younger than 35 years (1563; 78.3%), in a marital or common-law relationship (1901; 95.4%), had a household income higher than $\$80,000 (1406; 72.5%), and level of education higher than high school (1802; 90.5%). No differences were observed concerning maternal age at delivery, marital status and household income between the BMI categories, although obese women were more likely to be Caucasian and have attained lower levels of education than women with normal weight prior to pregnancy.

Comparison of obstetrical characteristics and maternal outcomes in labour and at delivery based on pre-pregnancy BMI are presented in Table 2. There was no difference in parity between the three groups of women. However, the history of delivery of a LGA baby was more frequent in obese and overweight women than in women of normal weight. A graded association was seen for the likelihood of pregnancy complications including pregnancy-induced hypertension, preeclampsia, eclampsia, diabetes mellitus, and placenta previa according to BMI category. The likelihood of spontaneous onset of labour decreased with increasing BMI, with obese women having the highest risk for labour induction (OR 2.5, 95% CI 1.8–3.3); almost half of the obese women had their labour induced. In addition, these women were more likely to deliver by emergency caesarean section (OR 2.5, 95% CI 1.6–3.8) and less likely to deliver by forceps or vacuum (OR 0.4, 95% CI 0.2–0.8) compared to normal weight women.

Newborn characteristics. Newborn characteristics are illustrated in Table 2. Fifty two percent of newborns from the cohort were male. No difference was observed in distribution of newborn gender among the BMI categories. Whereas 62.5% of the babies born to normal weight mothers were delivered full term (39$^{th}$ – 40$^{th}$ weeks gestation), the fetuses from overweight pregnancies were more likely to be delivered late term (41$^{st}$ – 44$^{th}$ weeks) (OR 1.5, CI 1.1–1.9) and the fetuses from obese pregnancies early term (37$^{th}$ – 38$^{th}$ weeks) (OR 1.9, CI 1.4–2.6). The median weight at birth was 3395 g (IQR 591), with newborns of overweight and obese women being heavier than newborns of normal weight women (3473 g (IQR 643) and, respectively, 3476 g (IQR 686) ($p < 0.05$ for both). Although no differences were observed between groups concerning the lower end of the birth weight curve (LBW and SGA), a linear relationship was observed between fetal macrosomia and maternal BMI. Infants of obese mothers were more likely to undergo resuscitation at birth (OR 1.4, CI 1.0–1.9).

Perinatal outcomes. Table 3 presents the adjusted models of the associations between perinatal outcomes including macrosomia, Apgar score, NICU admission and postnatal hospital stay and maternal BMI prior to pregnancy; the variables included in the models are presented in the supplemental data, Table S1. In multivariable regression analysis, the adjusted odds for delivering a macrosomic infant increased by half in overweight (OR 1.4, CI 1.1–2.1) and by two fold in obese women (OR 2.0, CI 1.2–3.1) as compared to lean women. Caucasian ethnicity, multiparity, and gestational age at delivery of 41 weeks or more were independently associated with the risk of macrosomia. In our model, history of...
delivery of a LGA infant was the strongest predictor of a macrosomic infant, increasing the risk about five times (OR = 4.94, CI 1.8–13.3) (Supplemental data, Table S1).

In our cohort of singleton pregnancies delivered at term in cephalic presentation, no differences were observed in the Apgar score, NICU admission and 48 h length of postnatal hospital stay between

Table 1 | Descriptive data of the study population across BMI categories

| Percent of study sample n (%) | Normal weight | Overweight | Obese | p-value |
|-----------------------------|--------------|------------|-------|--------|
| Maternal age at birth (years), median(IQR) | 31.0 (6) | 31.4 (5) | 30.5 (7) | 0.326 |
| Maternal pre-pregnancy weight (kg), median(IQR) | 60.0 (9.4) | 73.3 (9.9) | 93.1 (18.0) | <0.001 |
| Maternal height (cm), median(IQR) | 166.1 (8.1) | 165.1 (10.1) | 165.1 (10.1) | 0.585 |

| Ethnicity n (%) | Caucasian | Non-Caucasian | p-value |
|----------------|----------|--------------|--------|
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Table 2 | Comparison of obstetrical and neonatal characteristics between pre-pregnancy BMI categories

| Multiparity | Normal weight | Overweight | OR (CI) | p-value |
|-------------|--------------|------------|---------|--------|
| History of LGA | 7 (0.5) | 8 (1.7) | 3.2 (1.1–8.9) | 0.002 |
| Pregnancy complications | 173 (13.2) | 106 (22.5) | 1.9 (1.4–2.4) | <0.001 |
| Gestational age at delivery (weeks) | Early term 39/7–40/6 | 295 (22.5) | 1.0 (0.7–1.3) | 0.854 |
| Full term 41/7–42/6 | 820 (62.5) | 75 (35.5) | 1.9 (1.4–2.6) | <0.001 |
| Late term 43/7–44/6 | 194 (14.8) | 31 (14.7) | 0.9 (0.6–1.5) | 0.975 |
| Postterm | 4 (0.3) | 0 (0.0) | 0.7 (0.42–1.1) | 0.438 |
| Induction of labour | 366 (27.9) | 103 (48.8) | 2.5 (1.8–3.3) | <0.001 |
| Maternal indication | 7 (9.0) | 3 (4.7) | 0.4 (0.2–0.8) | 0.011 |
| Other | 1 (1.1) | 0 (0.0) | 0 (0.0) | 0.001 |
| Newborn gender | female | 620 (46.8) | 472 (23.6) | 211 (10.6) | 0.001 |
| male | 692 (52.8) | 240 (12.5) | 105 (50.2) | 1.1 (0.8–1.5) | 0.523 |
| SGA | 148 (12.0) | 45 (10.2) | 0.8 (0.5–1.1) | 0.318 |
| LBW | 23 (1.8) | 10 (2.1) | 1.2 (0.5–2.5) | 0.612 |
| Meconium in amniotic fluid | 250 (19.0) | 112 (23.7) | 1.3 (1.0–1.7) | 0.030 |
| Resuscitation | 582 (44.3) | 218 (46.2) | 1.0 (0.8–1.3) | 0.486 |

Abbreviations: BMI, body mass index; OR(95%CI), unadjusted odds ratio (95% Confidence Interval);
*Pregnancy complications include: pregnancy-induced hypertension, preeclampsia, eclampsia, diabetes mellitus and placenta praevia;
1SGA, Small for Gestational Age, birth weight below 10th percentile of sex-specific birth weight;
2LBW, birth weight below 2500 g;
3LGA, Large for Gestational Age, birth weight above 90th percentile of sex-specific birth weight;
*Newborn resuscitation at birth included any of the following methods alone or combined: suction, oxygen, bag/mask, endotracheal tube, cardiopulmonary resuscitation, medication;
1Normal weight = BMI 18.50–24.99 kg/m2, Overweight = BMI 25.00–29.99 kg/m2, Obese = BMI > 30.00 kg/m2.

In our cohort of singleton pregnancies delivered at term in cephalic presentation, no differences were observed in the Apgar score, NICU admission and 48 h length of postnatal hospital stay between
Table 3 | Perinatal outcomes across maternal pre-pregnancy BMI categories

|                       | Normal weight | Overweight | Obese |
|-----------------------|---------------|------------|-------|
|                       | n (%)         | Crude OR (95%CI) | Adjusted OR (95%CI) | n (%)         | Crude OR (95%CI) | Adjusted OR (95%CI) |
| Fetal macrosomia      | 107 (8.1)     | 1.6 (1.1–2.3) | 1.4 (1.1–2.1) | 31 (14.7)    | 1.9 (1.2–2.9) | 2.0 (1.3–3.2) |
| Apgar score <7 at 5 min | 23 (1.8)     | 2.0 (0.7–6.0) | 2.0 (0.6–6.2) | 2 (0.9)      | 1.8 (0.4–7.9) | 1.9 (0.4–8.9) |
| NICU admission        | 74 (5.6)      | 1.1 (0.6–1.6) | 1.1 (0.7–1.8) | 16 (7.6)     | 1.3 (0.7–2.4) | 1.4 (0.7–2.6) |
| LOS 24 hs             | 351 (52.4)    | 1.5 (1.1–2.1) | 1.4 (1.1–2.1) | 48 (55.8)    | 1.1 (0.7–1.8) | 1.0 (0.6–1.6) |
| LOS >48 hs            | 642 (95.8)    | 1.5 (0.6–3.7) | 1.1 (0.4–2.8) | 85 (98.8)    | 3.7 (0.5–27.6) | 5.5 (0.4–61.7) |

Abbreviations: BMI, body mass index; LOS, length of hospital stay; NICU, neonatal intensive care unit; OR, odds ratio; CI, confidence intervals.

Discussion

This prospective community-based study suggests that being overweight or obese does not independently increase the risks of low Apgar score at birth, admission to neonatal intensive care or increased postnatal hospital stay. However, our study demonstrates that increased maternal BMI before conception influences intrauterine growth and infant weight at delivery and labour and delivery outcomes. Importantly, the linear association between BMI and the risk of pregnancy complications, active management in labour and at delivery, including labour induction and surgical delivery, are evidence that contribute to the body of knowledge of the adverse effects of obesity on pregnancy and maternal health.

As expected, using birth weight as a proxy for intrauterine growth, we found that the risk of delivery of an infant with birth weight >4000 g increases with increasing maternal BMI prior to conception. This data aligns with other research that suggests a 1.5 to 2.3 increase in the adjusted odds of delivering large for date infants in obese women. Maternal obesity is a well-known risk factor for accelerated intrauterine growth, fetal macrosomia being consistently reported to associate with increased maternal body weight.

In this study, we used Apgar score, a conventionally, standardised tool that evaluates physical condition at birth as an indicator of the impact of maternal BMI on the vitality and wellbeing of the newborn. Low Apgar scores are predictive of adverse immediate (i.e. NICU admission, increased hospitalization) and long term outcomes (cognitive impairment, neurologic sequelae). No association was evident in our study between maternal overweight and obesity and low Apgar score at 5 min. Likewise, two other large studies evaluating fetal wellbeing in healthy obese women, found no differences in neonatal Apgar scores between lean and obese women. In contrast, studies in large cohorts from British and Danish populations reported increasing risk of low Apgar scores (<7) with increasing maternal BMI, after controlling for pregnancy complications.

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The inconsistency in findings of the associations between maternal BMI and Apgar scores may result from the differences between the characteristics of the populations or infants studied. Apgar score assessment, or BMI classification categories. Of note, in several of the pregnancy cohorts mentioned above, the studies spanned several years or even decades, possibly reflecting changing clinical practices over time. In contrast, our study covered a short, defined interval, but major changes in obstetrical practice were less likely to occur. Furthermore, we have excluded all preterm births from our study because the infants from these pregnancies are known to be at increased risks of poor neonatal outcomes. In contrast with above-mentioned studies, we report low prevalence of Apgar <7 (1.6%) that is, however, representative for Calgary metropolitan area (1.7%) and the province of Alberta (2.6%), and this may limit generalization of our findings. Additional studies are warranted to evaluate the impact of maternal obesity on Apgar score at delivery in specific populations.

In contrast with earlier studies that report an increased risk of admission to neonatal care for the children of obese mothers, we found no difference in NICU admission rates of the infants of obese and overweight women in comparison with infants of normal weight women. Other recent studies report no differences in NICU admission rates of neonates of severe and morbidly obese or normal weight mothers, in agreement with our findings. The discrepancy in...
providers of the potential risks of maternal and perinatal morbidity for healthy overweight and obese women who deliver at term, cephalic, and by cesarean delivery in otherwise healthy women with higher BMI. Mamun et al. concur, report only 2.5–3.8% admissions in a population selected on criteria similar with ours19,20.

Other studies have found an independent association between morbid obesity and LOS, or report that the increased hospital stay in overweight and obese pregnancies was largely mediated by pregnancy complications20,21,22. In our study, pregnancy complications did not increase the odds of duration of hospitalization among otherwise healthy women with higher BMI. Mamun et al concur, reporting on association between LOS and gestational weight gain, independent of pregnancy complications and mode of delivery23. Beside BMI classification, the variability of clinical practice regarding the appropriate duration of hospitalization at birth and the mode of LOS reporting (days vs hours) may explain, at least partially, the disagreement between findings from different studies including ours. The appropriate LOS has been a controversial issue for decades, a number of factors including maternal and neonatal health, health services and community resources playing a major role in the decision of maternal-child dyad hospital discharge. Currently, there is a trend of early hospital discharge for both mother and child following uncomplicated childbirth24,25. Among Canadian provinces and territories, in the period 2002–2003 to 2004–2005, the province of Alberta had the largest proportion (47.8 for 100 hospital live births) of term newborns discharged within two days of birth26.

A major strength of this study is represented by the prospective design of the study cohort. The relatively large sample size of the cohort permitted selection of a phenotyped population to study the effects of overweight and obesity on outcomes at birth. Similar to all observational studies, our study has inherent limitations such as potential for misclassification due to self-report; however, a number of our variable were extracted from the medical records which may decrease the risk for this bias27,28. Furthermore, due to the inclusion criteria, women with potential high risk of adverse perinatal outcomes (i.e. underweight at conception) were excluded from the study, which precluded examination of this weight category on outcomes. In addition, because of limited number of women with BMI > 40.0, we could not study separately the outcomes in all BMI obese categories. Therefore, our findings might not apply to morbidly obese women.

In conclusion, this study demonstrates that among otherwise healthy overweight and obese women who deliver at term, cephalic, singleton infants, pre-pregnancy BMI was not associated with low Apgar scores or increased health service utilization at birth. The relatively limited impact of obesity on perinatal outcomes found in the present study may suggest increased awareness of health care providers of the potential risks of maternal and perinatal morbidity in women with increased BMI. In addition, the growing literature on the subject over the past two decades and release of new and updated clinical guidelines and principle of practice may have contributed to better management and increased quality of care of healthy obese women who become pregnant. Moreover, our findings may suggest that perinatal care in tertiary centers may offset the risk factors of poor outcomes, as suggested previously by Stepan et al. This is an important aspect of this research which may have implications with respect to the costs of perinatal health care and decision of postnatal hospital discharge in pregnant overweight and obese women who are otherwise healthy.

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Acknowledgments
The authors gratefully acknowledge the participants involved in the All Our Babies cohort, the study research team and staff. Alberta Innovates Health Solutions (AI-HS) provided funding for the cohort through an Interdisciplinary Team Grant (Preterm Birth and Healthy Outcomes #200700595). AEV holds an ACHRI-CIHR fellowship award.

Author contributions
A.V. conceived and designed the study with input from S.T. and S.M.W. A.V. undertook the analysis and interpretation of the data with input from S.T., S.M.W. and D.S. A.V. wrote the first draft of the manuscript. S.C.T. was involved in AOB study design and acquisition of funding, and is responsible for overall integrity, progress and timely completion of the AOB study. S.W.M. was responsible for the management, coding, linkage of cohort data. D.S. is an investigator with AOB study. All authors participated in the editing of the manuscript and approved the final version for publication.

Additional information
Supplementary information accompanies this paper at http://www.nature.com/scientificreports

Competing financial interests: The authors declare no competing financial interests.

How to cite this article: Vinturache, A.E., McDonald, S., Slater, D. & Tough, S. Perinatal outcomes of maternal overweight and obesity in term infants: a population-based cohort study in Canada. Sci. Rep. 5, 9334; DOI:10.1038/srep09334 (2015).

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