BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022220
Article Type:	Research
Date Submitted by the Author:	09-Feb-2018
Complete List of Authors:	McRae, Daphne; University of British Columbia, School of Population and Public Health Janssen, Patricia; University of British Columbia, School of Population and Public Health Vedam, Saraswathi; University of British Columbia, Birth Place Lab, Department of Family Practice Mayhew, Maureen; University of British Columbia, School of Population and Public Health Mpofu, Deborah; University of Saskatchewan, Dept. of Community Health and Epidemiology; Saskatoon Health Region, Saskatoon City Hospital Teucher, Ulrich; University of Saskatchewan, Dept. of Psychology Muhajarine, Nazeem; University of Saskatchewan, Dept. of Community Health and Epidemiology
Keywords:	midwifery, socioeconomic status, birth outcomes, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Fetal medicine < OBSTETRICS, Maternal medicine < OBSTETRICS

Reduced prevalence of small-for-gestational-age and preterm birth for women of low socioeconomic position: a population-based cohort study comparing antenatal midwifery and physician models of care

Correspondence to:|
Daphne McRae
School of Population and Public Health,
University of British Columbia
2206 E Mall, Vancouver BC Canada V6T 1Z3
Ph: +1 604-794-7729 Fax : +1 604-822-0640
daphne.mcrae@ubc.ca

Patricia A Janssen
School of Population and Public Health,
University of British Columbia
2206 East Mall Vancouver BC Canada V6T 1Z3

Saraswathi Vedam
Birth Place Lab, Dept. of Family Practice
University of British Columbia
Suite 304 - 5950 University Boulevard Vancouver BC Canada V6T 1Z3

Maureen Mayhew
School of Population and Public Health
University of British Columbia
2206 East Mall Vancouver BC Canada V6T 1Z3

Deborah Mpofu
Saskatoon City Hospital
Saskatoon Health Region
701 Queen Street, Saskatoon SK S7K 0M7
and
Dept. of Community Health and Epidemiology
University of Saskatchewan
Box 7 Health Science Building 107 Wiggins Road Saskatoon SK Canada S7N 5E5

Ulrich Teucher
Dept. of Psychology
University of Saskatchewan
9 Campus Drive Saskatoon SK Canada S7N 5A5

Nazeem Muhajarine
Dept. of Community Health and Epidemiology
University of Saskatchewan

Box 7 Health Science Building 107 Wiggins Road Saskatoon SK Canada S7N 5E5

Keywords: midwifery, socioeconomic status, birth outcomes, quality in health care, fetal medicine, maternal medicine

Word count: 3,886

ABSTRACT

Objective: Our aim was to investigate if antenatal midwifery care was associated with lower odds of small-for-gestational-age (SGA) birth, preterm birth (PTB), or low birth weight (LBW) compared to general practitioner (GP) or obstetrician (OB) models of care for women of low socioeconomic position.

Setting: This population level, retrospective cohort study used province-wide maternity, medical billing, and demographic data from British Columbia, Canada.

Participants: Our study included 57,872 pregnant women, with low socioeconomic position, who: were residents of British Columbia, Canada, carried a singleton fetus, had low to moderate medical/obstetric risk, delivered between 2005-2012, and received medical insurance premium assistance.

Primary and secondary outcome measures: We report rates, adjusted odds ratios (aOR), and 95% confidence intervals for the primary outcome, SGA birth (< the 10th percentile), and secondary outcomes, PTB (< 37 weeks completed gestation), and LBW (< 2,500 g.).

Results: Our sample included 4,705 midwifery patients, 45,114 GP patients, and 8,053 OB patients. Odds of SGA birth were reduced for patients receiving antenatal midwifery vs. GP (aOR 0·71, 95% CI: 0·62-0·82) or OB care (aOR 0·59, 95% CI: 0·50-0·69). Odds of PTB were lower for antenatal midwifery vs. GP (aOR 0·74, 95% CI: 0·63-0·86) or OB patients (aOR 0·53, 95% CI: 0·45-0·62). Odds of LBW were reduced for midwifery vs. GP (aOR 0·66, 95% CI: 0·53-0·82) or OB patients (aOR 0·43, 95% CI: 0·34-0·54).

Conclusion: Antenatal midwifery care in British Columbia, Canada was associated with lower odds of SGA birth, PTB, and LBW, for women of low socioeconomic position, compared to

physician models of care. Results support the development of policy to ensure antenatal midwifery care is available and accessible for women of low socioeconomic position. Future research is needed to determine the underlying mechanisms linking midwifery care to better birth outcomes for women of low socioeconomic position.

Strengths and limitations of this study

- A large, population-level cohort study (57,872) representing the majority of pregnant women with low socioeconomic position in British Columbia, Canada (2005-2012)
- A rigorous modelling approach controlled for correlation in outcomes at a family and community level
- Findings are generalizable to other high resource settings which offer similar, publicly funded midwifery services
- Limited by self-selection of care provider, which could have introduced differences between cohorts in social/health risks not documented in the maternity record
- A post hoc analysis controlling for antepartum morbidity was conducted to assess the magnitude of self-selection bias

INTRODUCTION

As established in the literature, women of low socioeconomic position (SEP) are more susceptible to poor infant birth outcomes compared to women of higher SEP.[1] In response to this inequity, researchers have sought to determine if antenatal midwifery care could minimize the risk of adverse newborn outcomes for women of low SEP. In a 2016 scoping review of randomized trials and observational studies from high resource countries (1990 to 2015), comparing antenatal midwifery versus physician-led care for women of low SEP,[2] results indicated lower risk of preterm birth (PTB),[3] low birth weight (LBW)[4], and/or very low birth weight (VLBW)[4,5] for midwives' patients in some studies (or subpopulations within studies), yet other studies indicated no significant difference in outcomes by provider-type.[6-8] Almost all of these studies were limited by non-representative sampling,[3,6,7] inadequate study power,[6,8-10] and/or failure to control for confounders.[4,6] All but one study[6] were conducted in the United States. Addressing these limitations, we conducted a large, population level study among women of low SEP with low to moderate medical/obstetric risk to investigate if antenatal midwifery care was associated with lower odds of small-for-gestational-age (SGA) birth, PTB, or LBW compared to general practitioner (GP) or obstetrician (OB) models of care.

METHODS

Study design

Using a retrospective cohort design we examined the association between antenatal models of care and odds of SGA birth, PTB, or LBW among women of low SEP with low to moderate medical/obstetric risk. Model of care was ascertained using practitioners' antenatal service billing records. In British Columbia (BC) GPs and OBs are compensated by the Ministry of

Health for each antenatal visit whereas midwives are compensated according to partial or full trimester of care. Antenatal care with a GP was defined as greater than or equal to three routine antenatal visits with a GP, and less than or equal to one routine antenatal visit with an OB, or less than or equal to one partial trimester of midwifery care. Antenatal care with an OB was operationalized as greater than or equal to three routine antenatal visits with an OB, and less than or equal to one routine antenatal visit with a GP, or less than or equal to one partial trimester of midwifery care. Antenatal midwifery care was operationalized as greater than or equal to two partial or full trimesters of midwifery care (equivalent to a *minimum* exposure of three routine antenatal physician visits), and less than or equal to one routine GP or OB antenatal visit. Obstetrician consultations were not included as routine antenatal visits. Ethics approval for this study was granted from the University of Saskatchewan, Biomedical Research Ethics Board (Reg. No. #1 00001471, #2 00008358) and the University of British Columbia, Children's and Women's Health Center of BC Research Ethics Board (Reg. No. H14-01629).

In BC women select their preferred type of maternity caregiver depending on practitioner availability and as appropriate to their need for specialist care. In rare instances women may have planned, shared-care between a small pool of midwives and GPs. Midwifery care in the Canadian context is equivalent to caseload midwifery care as it is practiced in Australia, the UK, and other European countries. Midwives provide holistic, continuity of care in which a midwife, or a small pool of midwives, known to a women is/are available on-call 24 hours a day.[11] The midwifery model is relationship-based with antenatal appointments lasting 30 to 60 minutes on average[12] to facilitate counselling, education, emotional support, and informed choice.[11] When a midwifery patient has moderate perinatal risk, as outlined in the BC College of Midwives'

guidelines,[13] midwives are required to consult with a physician (generally an OB) and if high-risk complications arise they will recommend a transfer to OB care.

While many GPs and some OBs function in a continuity of care, relationship-based model, the volume of need and fee-for-service funding model for physicians leads to shorter antenatal visits. Within the midwifery model, fees are all inclusive based on care and annual caseloads are limited allowing for longer antenatal visits on average.[11] All three types of providers follow the same schedule of antenatal visits.

Outcomes

Our outcome data for this study was obtained from the BC Perinatal Data Registry (PDR).[14] Registry data was abstracted from hospital and home birth records. As well, International Statistical Classification of Diseases (ICD-10-CA) codes were imported to the PDR from the Canadian Institutes of Health Information Discharge Abstract Database. The PDR captures approximately 99% of all BC births with validation studies reporting a 97% accuracy rate over all data fields.[15]

The primary outcome variable was SGA birth (< 10th percentile) according to Kierans and colleagues' sex-specific birth weight charts.[16] Secondary outcomes included PTB (< 37 weeks completed gestation), and LBW (< 2,500 g.). LBW may be attributable to PTB, intrauterine growth restriction, or both and is reported here to facilitate comparison with other studies.

Study sample

Our study sample included women who: were residents of BC, received antenatal midwifery, GP or OB care, carried a singleton fetus, had low to moderate medical/obstetric risk, delivered between 1 January 2005 and 31 December 2012, received medical insurance premium assistance, and were not registered Status Indian. Women were classified as having low to moderate medical and obstetric risk if they were eligible for midwifery care throughout the antenatal period according to guidelines produced by the College of Midwives of BC[13] and expert advice from our clinical team members. Conditions rendering women ineligible for midwifery care included diseases of the blood, blood forming organs or of the circulatory system, pre-existing hypertension or diabetes, liver disorders, tuberculosis, or malaria, as recorded in the maternity record, history of more than one PTB, more than two caesarean section deliveries, or more than two spontaneous abortions (prior to 20 weeks completed gestation), or in the current pregnancy pre-eclampsia/eclampsia, placenta previa with hemorrhage, isoimmunisation, incompetent cervix, hyperemesis gravidarum with metabolic disturbance, or age less than 14 years. (See Appendix A for a complete description of inclusion/exclusion variables and ICD 10-CA codes.)

Because the key indicator used to assess low SEP, medical insurance premium assistance, was not available for Status women (they had their insurance premiums paid through Health Canada) they were excluded from the study. We operationalized low SEP as receipt of BC Medical Services Plan (MSP) regular premium subsidy assistance during the year of delivery.[17] Eligibility for this assistance is based on family, net income ceiling exclusive of federal or provincial childcare or disability benefits. During the study period the ceiling ranged from $24,000 to $30,000 for a family of three depending on the year of receipt.[17] This is comparable to Statistics

Canada's before-tax, low income cut-off for a family of three ($23,358 to $33,933 as of 2008),which is a standard measure of poverty.[18]

Sample Size Estimates

During the study period women living in the poorest neighbourhood income quintiles in Canada experienced a 9·9% prevalence of SGA.[19] To detect an absolute difference in prevalence of 3% from a baseline of 9·9% we required 1,394 women in each exposure category with type I error set at p=0·05 two sided, and a type II error set at 0·20. We estimated 16·2% of the total BC population received MSP premium assistance,[20] equivalent to 4,154 midwifery patients and 36,255 physician patients during the study period, excluding those who would not meet our criteria for low to moderate obstetrical risk. Sample size calculations were conducted using OpenEpi 3.01.

Statistical Analyses

To assess the association of model of care and SGA, PTB, and LBW, we developed logistic regression models using a Generalized Estimating Equation approach.[21] This method allowed for adjustment of variance estimates to accommodate potential correlation for women delivering multiple infants during the study period and for clustering of effects by community.[21] Differing correlation structures were specified and compared using the Quasi-Likelihood Under the Independence model Criteria (QIC) to determine the most appropriate correlation structure (the smaller the QIC the better the structure's fit).[21] Binomial distributions were specified and models fitted with an exchangeable correlation structure (in which observations from the same cluster are assumed to be equally correlated) using logit link functions.[21]

We identified potential confounders, tested in our model, from the literature and based on our clinical experience. Variables analyzed from the PDR included maternal age, parity, medical risk, prior obstetric risk, pre-pregnancy BMI, infant sex, delivery year, smoking status, substance use, alcohol use, mental illness, and northern residence. (See Appendix B for a complete list of covariate descriptions, data sources, and ICD 10-CA codes.) From the Province of BC Statistics Division (BC Stats) we obtained socioeconomic rankings and income inequality rankings for each Local Health Area (LHA)—89 geographic and health administrative regions in BC that aggregate to larger Health Authorities.[22] Income inequality rankings were based on the proportion of each LHA's total income from all households earning less than the median income compared to each LHA's total income from all households. In an entirely equitable LHA the poorest half of the households would garner 50% of the total income.[22] We tested this variable as a potential confounder because it has been hypothesized that residence in a high income inequality area may increase the risk of poor self-concept potentially leading to lower commitment to pregnancy and unhealthy lifestyle choices.[23] From the BC Ministry of Health we received data on women's neighbourhood income quintile, depending on residential postal code at delivery,[24] and receipt of social assistance[17]—public financial assistance granted to low income individuals.

In logistic regression univariate analyses we identified variables that had Wald chi-square values of $p < 0{\cdot}25$ and retained these for our initial multivariable models.[25] For the final variable selection we used a manual, backward elimination approach. Variables with a Wald chi-square p-value $\geq 0{\cdot}05$ were excluded from each multivariable model one at a time, beginning with the

variable having the largest p-value.[25] After suspected confounders were removed from a model, coefficient estimates from models with and without the variable were examined to determine if the exclusion produced a greater than 20% change in any coefficient in the model. If this magnitude of change was detected, indicating a meaningful adjustment to (an)other variable(s), the eliminated variable was returned to the model.[25, p92] This process was repeated until only variables meeting the criteria or those of clinical significance remained in the model. For births with no missing information we report unadjusted and adjusted odds ratios and 95% confidence intervals for SGA, PTB, and LBW by model of care.

Lastly, we investigated residual confounding potentially arising from self-selection bias associated with pre-existing morbidity. If, for example, women chose OB care because of prior health conditions which were not documented in the PDR, then the OB cohort could be comprised of systematically higher-risk patients. To control for these conditions we repeated our regression modelling using our final models with adjustment for select antepartum morbidities (see definition in Table 1). SAS Enterprise 7·1 (SAS Institute, Cary, NC, USA) was used for data analysis.

Table 1: Frequencies and proportions of maternal characteristics by antenatal model of care, British Columbia, 2005-2012 (n=57,872)

Characteristics	Antenatal Model of Care		
	MW n=4,705 (%)	GP n=45,114 (%)	OB n=8,053 (%)
Age (yrs.)			
14-19	155 (3·29)	4,697 (10·41)	338 (4·20)
20-24	893 (18·98)	14,789 (32·78)	1,447 (17·97)
25-29	1,619 (34·41)	13,161 (29·17)	2,303 (28·60)
30-34	1,362 (28·95)	7,966 (17·66)	2,113 (26·24)
35-39	573 (12·18)	3,730 (8·27)	1,387 (17·22)
≥40	103 (2·19)	771 (1·71)	465 (5·77)
Parity[a]			
Nullipara	2,177 (46·27)	23,141 (51·30)	3,617 (44·91)
Multipara	2,528 (53·73)	21,972 (48·70)	4,435 (55·07)
Medical risk[b,c]	14 (0·30)	414 (0·92)	132 (1·64)
Prior obstetric risk[b,d]	124 (2·64)	1,669 (3·70)	478 (5·94)
Mental illness[b,e]	1,020 (21·68)	5,146 (11·41)	610 (7·57)
Receiving social assistance[b]	310 (6·59)	5,833 (12·93)	814 (10·11)
Pre-pregnancy Body Mass Index (BMI)[f]			
Underweight	229 (4·87)	2,300 (5·10)	519 (6·44)
Normal	2,612 (55·52)	16,777 (37·19)	2,990 (37·13)
Overweight	689 (14·64)	5,829 (12·92)	877 (10·89)
Obese	335 (7·12)	3,792 (8·41)	479 (5·95)
Unknown	840 (17·85)	16,416 (36·39)	3,188 (39·59)
Smoking Status			
Never	992 (21·08)	6,666 (14·78)	1,868 (23·20)
Former	690 (14·67)	5,028 (11·15)	434 (5·39)
Current	471 (10·01)	9,910 (21·97)	800 (9·93)
Unknown	2,552 (54·24)	23,510 (52·11)	4,951 (61·48)
Substance use in pregnancy[b,g]	179 (3·80)	3,273 (7·25)	302 (3·75)
Alcohol identified as a risk[b]	57 (1·21)	1,109 (2·46)	63 (0·78)
Utilization of prenatal care[h]			
Intense	98 (2·08)	304 (0·67)	60 (0·75)
Adequate	1,420 (30·18)	6,851 (15·19)	902 (11·20)
Intermediate	1,927 (40·96)	19,929 (44·17)	2,601 (32·30)
Inadequate	273 (5·80)	6,986 (15·49)	980 (12·17)
Unknown	987 (20·98)	11,044 (24·48)	3,510 (43·59)
Antepartum morbidity[b,i]	349 (7·42)	6,843 (15·17)	1,955 (24·28)
Delivery year			
2005	307 (6·52)	5,772 (12·79)	955 (11·86)
2006	437 (9·29)	6,028 (13·36)	1,002 (12·44)
2007	471 (10·01)	6,133 (13·59)	1,074 (13·34)

2008	512 (10·88)	5,892 (13·06)	977 (12·13)
2009	606 (12·88)	5,640 (12·50)	910 (11·30)
2010	694 (14·75)	5,371 (11·91)	1,000 (12·42)
2011	796 (16·92)	5,337 (11·83)	1,014 (12·59)
2012	882 (18·75)	4,941 (10·95)	1,121 (13·92)
Neighbourhood SEP[j]			
High	624 (13·26)	4,984 (11·05)	646 (8·02)
Low/Medium	4,081 (86·74)	40,130 (88·95)	7,407 (91·98)
Local Health Area (LHA) Population Demographic[k]			
Urban	4,548 (96·66)	42,489 (94·18)	7,889 (97·96)
Rural	145 (3·08)	2,576 (5·71)	145 (1·80)
Unknown	12 (0·26)	49 (0·11)	19 (0·24)
LHA Socioeconomic Rank[l]			
High (Best)	2,638 (56·07)	13,287 (29·45)	4,043 (50·20)
Medium	1,472 (31·29)	22,011 (48·79)	3,197 (39·70)
Low	582 (12·37)	9,710 (21·52)	739 (9·18)
Unknown	13 (0·28)	106 (0·23)	74 (0·92)
LHA Income Inequality Rank[m]			
High (Worst)	1,667 (35·43)	10,635 (23·57)	4,177 (51·87)
Medium	2,326 (49·44)	25,544 (56·62)	3,311 (41·12)
Low	699 (14·86)	8,841 (19·60)	530 (6·58)
Unknown	13 (0·28)	94 (0·21)	35 (0·43)
Northern Residence[b,n]	136 (2·89)	6,032 (13·37)	291 (3·61)

All characteristics examined differed significantly by model of care (X^2 $p < 0·0001$)

[a] missing cases amount to 5 or less

[b] values represent cases classified as "Yes", the remainder of the cases were classified as "No", "Unknown", or were undocumented

[c] included maternal disease of the respiratory or digestive system, and endocrine, nutritional, or metabolic disease

[d] included women with at least one of the following conditions in past pregnancy: infant with major congenital anomaly, neonatal death, stillbirth, or one preterm delivery

[e] included any of the following diagnoses prior to, or during the current pregnancy: anxiety disorder, depression, postpartum depression, bipolar disorder, other/unknown (including schizophrenic, mood, and psychotic disorders)

[f] classified according to Health Canada's guidelines[26]

[g] heroin/opioids, cocaine, methadone, solvents, marijuana, or other/unknown drugs used at any time during pregnancy, prescription or other drug use identified as a risk at any time during pregnancy

[h] classifications based on Kotelchuck's Adequacy of Prenatal Care Utilization Index[27]

[i] included pregnancy induced hypertension, gestational diabetes (whether or not insulin dependent), anemia, intrauterine growth restriction, viral disease, infection and parasitic disease, placenta previa without hemorrhage, polyhydramnios or oligohydramnios, antepartum hemorrhage $\geq$ 20 weeks, sexually transmitted infection or HIV, or premature separation of the placenta

[J] neighbourhood income quintiles were classified as low/medium (quintiles 1-4) vs. high (quintile 5)[24]
[k] rural LHAs had a population < 10,000 people
[l] calculated by BC Stats, based on a range of social determinants of health reflecting area-level economic and social processes, and policy decisions[22]
[m] calculated by BC Stats[22]
[n] at the time of delivery, normal residence in BC's Northern Health Authority

RESULTS

There were 4,705 midwifery, 45,114 GP, and 8,053 OB pregnancies included in the study (Figure 1). Both midwives' and OBs' patients were, on average, older than GPs' patients, more likely to be multiparous, non-smokers, and residing in urban areas (Table 1). In addition, midwifery and OB patients less frequently reported alcohol or substance use during pregnancy compared to GP patients. A higher proportion of GP and OB patients had moderate medical risk and prior obstetric risk than midwifery patients, though midwifery patients had higher prevalence of reported mental illness during or prior to pregnancy (Table 1). Midwife and GP patients had higher rates of overweight or obese BMI than OB patients. Midwives' patients also had higher prevalence of adequate attendance at prenatal care compared to physicians' patients.

Of all pregnancies in our study, 7·09% were SGA, 6·50% were PTB, and 3·32% were LBW (Table 2). On average there was a significant reduction in unadjusted odds of SGA for midwifery vs. GP patients (OR 0·67, 95% CI: 0·58 to 0·77) and midwifery vs. OB patients (OR 0·55, 95% CI: 0·47 to 0·64). GP vs. OB patients were also less likely to have a SGA infant (OR 0·81, 95% CI: 0·75 to 0·89). When controlling for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status, substance use, mental illness, and LHA socioeconomic rank, women receiving antenatal care from midwives vs. GPs had lower odds of having a SGA infant (aOR 0·71, 95% CI: 0·62 to 0·82) (Table 2). Midwifery vs. GP patients also had lower adjusted odds of SGA birth (aOR 0·59, 95% CI: 0·50 to 0·69). GP antenatal care was likewise associated with lower adjusted odds of SGA birth compared to OB care (aOR 0·83, 95% CI: 0·76 to 0·91).

The unadjusted odds of PTB were lower for woman receiving antenatal care from midwives vs. GPs (OR 0·68, 95% CI: 0·59 to 0·79) and midwives vs. OBs (OR 0·49, 95% CI: 0·41 to 0·57).

GP vs. OB patients also had lower unadjusted odds of PTB (OR 0·71, 95% CI: 0·65 to 0·78). When adjusting the PTB model for the same variables as the SGA model, as well as for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, neighbourhood SEP, LHA income inequality, and northern residence, odds of PTB remained statistically significantly lower for midwifery vs. GP care (aOR 0·74, 95% CI: 0·63 to 0·86) and midwifery vs. OB care (aOR 0·53, 95% CI: 0·45 to 0·62). On average, GP patients also had lower adjusted odds of PTB compared to OB patients (aOR 0·72, 95% CI: 0·65 to 0·79).

Women receiving antenatal midwifery care had lower unadjusted odds of LBW compared to those in the care of GPs (OR 0·60, 95% CI: 0·49 to 0·74) or OBs (OR 0·39, 95% CI: 0·31 to 0·50). GP vs. OB patients also had lower unadjusted odds of LBW (OR 0·65, 95% CI: 0·58 to 0·73). After adjustment for maternal age, parity, prior obstetric risk, pre-pregnancy BMI, infant sex, smoking status, and substance use, women in the care of midwives had lower odds of LBW compared to GP (aOR 0·66, 95% CI: 0·53 to 0·82) or OB patients (aOR 0·43, 95% CI: 0·34 to 0·54). GP patients also had lower adjusted odds of LBW compared to OB patients (aOR 0·65, 95% CI: 0·58 to 0·74).

When testing for residual confounding by controlling for select antepartum morbidities the associations between model of care and SGA, PTB, and LBW were attenuated but remained statistically significant (see Appendix C).

Table 2: Frequencies, proportions and adjusted odds ratios for small-for-gestational-age birth, preterm birth, and low birth weight by antenatal model of care, British Columbia, 2005-2012

	MW n= 4,705	GP n= 45,114	OB n= 8,053	MW vs. GP	MW vs. OB	GP vs. OB
	n(%)	n(%)	n(%)	OR (95% CI)	OR (95% CI)	OR (95% CI)
SGA[a]	227/4,695 (4·83)	3,179/45,002 (7·06)	689/ 8,025 (8·59)	0·71 (0·62-0·82)	0·59 (0·50-0·69)	0·83 (0·76-0·91)
PTB[b]	207/4,702 (4·40)	2,848/45,028 (6·32)	698/8,033 (8·69)	0·74 (0·63-0·86)	0·53 (0·45-0·62)	0·72 (0·65-0·79)
LBW[c]	91/4,704 (1·93)	1,438/45,091 (3·19)	393/8,046 (4·88)	0·66 (0·53-0·82)	0·43 (0·34-0·54)	0·65 (0·58-0·74)

All models adjusted for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status and substance use.
[a]Model also adjusted for mental illness, and LHA socioeconomic rank. Odds ratios based on 4,095 births with SGA and 57,722 total births with no missing information for this analysis.
[b]Model also adjusted for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, mental illness, neighbourhood SEP, LHA socioeconomic rank, LHA income inequality, and northern residence. Odds ratios based on 3,753 PTB births and 57,763 total births with no missing information for this analysis.
[c]Model also adjusted for prior obstetric risk. Odds ratios based on 1,922 births with LBW and 57,841 total births with no missing information for this analysis.

DISCUSSION

Strengths and Weaknesses

Our study demonstrated a statistically significant reduction in odds of SGA, PTB, and LBW for infants born to women of low SEP receiving antenatal midwifery vs. physician-led care in BC, Canada. This study represented the majority of pregnant, low SEP women in BC during the study period, had adequate study power, and tested a wide range of individual and area-level potential confounders. In addition, GEE logistic regression modelling allowed us to account for correlation in outcomes at a family and community level, a more rigours modelling approach than the methods used in previous studies. As this was a large, population based study, findings are generalizable for other high resource countries which offer similar, publicly funded midwifery services.

Our study was limited by its observational design. Until more women are willing to be randomly assigned to midwifery vs. physician-led care, evidence for causality will need to be established by repeated observational studies with representative samples over time. This study was also limited by a lack of data on the use of universal, objective screening tools for alcohol/substance use and mental health conditions, and it did not include measures of severity. In addition, there was no data available on race/ethnicity, language, or culture, and we were not able to assess outcomes among women who were Status Indians.

Women in the study self-selected their care provider, therefore it is possible that those with higher perinatal risk (on the low to moderate risk spectrum) chose obstetrician care, creating a higher risk OB cohort. However, we did control for a wide range of known medical and obstetric

risk factors when indicated, and when we controlled for antepartum morbidity the main associations remained significant. Overall the sample had a very low proportion of medical risk (0.97%) or prior obstetric risk patients (3.92%). Lastly, because women utilizing midwifery care in BC may need to be pro-active in ascertaining services early in pregnancy due to high demand, it is plausible that women who secured midwifery care were more knowledgeable about the health care system, more invested in their health, or had greater ability to pursue preferred health care services. These skills, attitudes, and values could have systematically differed between cohorts. Nonetheless, we did control for smoking, alcohol, and pre-pregnancy BMI, which may reflect women's attitudes, beliefs, and values during pregnancy, and this may have minimized self-selection bias.

Results in comparison with other studies

Observational studies with non-representative samples (a freestanding birth centre serving primarily low income African American women,[3] and an Australian, hospital-based cohort study restricted to women ≤ 21 years of age[28]) have reported similar findings. Likewise, in a randomized controlled trial for low SEP women who had high risk of delivering LBW infants, odds of VLBW was significantly lower among a subgroup of African American nurse-midwifery patients vs. OB patients (OR 0·35, 95% CI: 0·1 to 0·9).[5] However, there was no difference in odds of LBW or VLBW by practitioner-type in the overall sample. Additionally, in a retrospective cohort study[4] comparing outcomes of nurse-midwifery care to usual care for Medicaid recipients or uninsured patients residing in Westchester County, New York, nurse-midwifery patients had significantly lower risk of LBW and VLBW. Yet, in this study there was no adjustment for pre-existing health complications or perinatal risk which may have introduced bias.

Five other midwifery/physician studies involving women of low SEP have reported no significant differences in SGA or PTB by provider-type.[6-10] Almost all studies were limited by failure to control for pre-existing medical/obstetric risk[6] or inadequate power to detect clinically important differences between cohorts.[6,8-10] In one adequately powered, prospective cohort study (n=2,957)[7] comparing collaborative birth center care provided by midwives (with OB referral for complications) vs. OB or OB resident care, no statistically significant differences were reported. This study, however, was conducted in the U.S. and comprised of 77% Hispanic women.

Experience of antenatal care across models

In our study, adequate antenatal care utilization may have been a mechanism linking midwifery care to reduced odds of SGA, PTB, and LBW. Midwives' patients had 2·3 times greater odds of adequately utilizing antenatal care compared to GPs' patients and 2·5 times greater odds compared to OBs' patients. As revealed in a 2009 qualitative meta-synthesis, antenatal care use by marginalized women is associated with their perception of their clinician's trustworthiness, cultural sensitivity, and respect for life experience.[29] Adequate use of antenatal care has been shown to protect against PTB, stillbirth, and neonatal and infant death.[30] If midwifery's relationship-based model of care encouraged antenatal care uptake, it may have indirectly affected prevalence of infant morbidity for women of low SEP.

Lack of patient trust may also have inhibited patient disclosure of compromising health conditions. Midwifery patients had higher prevalence of mental illness overall and for each category (i.e. depression, anxiety, bipolar disorder) compared to GP or OB patients. Midwives'

patients had a 2·2 fold increase in odds of documented mental illness, compared to GPs' patients and a 3·4 fold increase compared to OBs' patients. In our study, prevalence of depression for midwifery patients approximated that reported in the literature. In a review of 16 antenatal and postnatal depression studies (n=35,419) which were published between 2000 and 2016, and mainly conducted in western Europe, researchers reported a mean antenatal depression prevalence of 17·2%.[31] In our study, data on depression was collected between 2008 to 2012. The proportion of midwifery patients with depression prior to or during pregnancy was 18·8% in contrast to 12·8% for GP patients and 7·4% for OB patients.

Greater disclosure of sensitive information to midwives providing caseload midwifery care has been noted in other studies. In the Australian midwifery cohort study previously cited, young women receiving caseload midwifery care were significantly ($p < 0·01$) more likely to report a history of mental illness, illicit drug use, and involvement with the Department of Child Safety than those receiving standard maternity care.[28] Likewise, in a small retrospective cohort study (n=194) conducted in the U.K. researchers examined birth outcomes by caseload midwifery care to standard maternity care for women with vulnerabilities (i.e. experiencing "domestic violence, homelessness, mental health issues, substance and/or alcohol abuse").[32, p411] Women in the caseload midwifery cohort were statistically significantly more likely to receive a referral to psychiatric care and/or domestic violence or other support services which may be indicative of higher rates of disclosure among midwifery patients. Of note, in both of these studies patients in the caseload midwifery cohorts had either a higher mean number of antenatal appointments[32] or a lower percentage of inadequate prenatal utilization of care (< 5 visits).[28] This likely increased

clinician-patient familiarity which is a component of trust shown to influence domestic abuse disclosure.[33]

In our study, odds of antepartum morbidity were lower for midwives' vs. physicians' patients providing another clue as to the mechanisms linking midwifery care to a reduction in prevalence of SGA, PTB, and LBW. Midwifery vs. GP patients had 59% lower odds of antepartum morbidity (see definition in Table 1), and midwifery vs. OB patients had 74% lower odds. When controlling for antepartum morbidity odds of SGA, PTB, and LBW by model of care were attenuated but remained statistically significant (Appendix C). This suggests that even if antepartum morbidity were related to baseline differences in health status (selection bias), this could only partially explain the lower odds of adverse infant birth outcomes for women in the care of midwives vs. physicians. It is plausible longer appointment times and a holistic approach to care may have made it possible for midwives to identify pre-morbid conditions (i.e. borderline hypertension or anemia) earlier in pregnancy and implement preventative measures before conditions progressed to antepartum morbidity.

Implications

Study findings indicate a need for policy which supports midwifery availability and accessibility for women of low SEP. Future studies are needed to identify which attributes of midwifery care influence infant birth outcomes for women of low SEP and the mechanisms (i.e. physiological, psychological and/or behavioural) underlying this association. In our study midwifery care was associated with the lowest odds of adverse birth outcomes followed by GP, then OB care. Antenatal midwifery and GP practice may have greater similarity (with respect to continuity in

care, provision of emotional support, and volume of medical intervention) than midwifery to OB care. Therefore, it could be useful to analyze characteristics of practice common to midwifery and GP care but which differ from OB practice.

CONCLUSION

Our study demonstrated lower odds of SGA birth, PTB, and LBW for women of low SEP in BC who received antenatal midwifery vs. physician-led care. As this was a large, population based study with adequate study power and control for confounders, our results are generalizable to other high resource countries offering similar midwifery services. Results of this study support the development of policy to ensure antenatal midwifery care is available and accessible for women of low SEP. Further research is needed to determine the mechanisms linking antenatal midwifery care to better birth outcomes among women of low SEP.

ACKNOWLEDGMENTS

We thank Celeste Bickford for assistance in linking the Research Extracts and data preparation. DNM was supported by an Arthur Smyth Scholarship from the College of Medicine, and a PhD Scholarship from the Department of Community Health and Epidemiology, University of Saskatchewan, SK, Canada. PAJ is supported by a Senior Scholar salary award from the BC Children's Hospital Research Institute, Vancouver, BC, Canada.

Disclaimers

All inferences, opinions, and conclusions drawn in this study are those of the authors, and do not reflect the opinions or policies of the Data Stewards. Authors have no competing interests to

declare. Funding sources had no involvement in the study; the authors are independent of all funders.

Contributors

DNM designed the study, conducted the statistical analyses, interpreted the results, drafted the initial manuscript, and revised subsequent drafts. NM and PAJ designed the study, reviewed the statistical analyses, interpreted the results, and reviewed and revised the manuscript. SV, MM and DM contributed to study design and clinical interpretation, and reviewed and revised the manuscript. UT contributed to interpretation, and reviewed and revised the manuscript. All authors approved the final manuscript.

Data Sharing

No additional data available.

Figure Legend

Figure 1: Eligibility flow chart Total number of pregnancies meeting inclusion/exclusion criteria by cohort.

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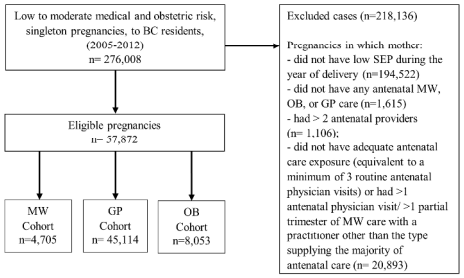

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APPENDIX A: Inclusion/exclusion variables and ICD 10-CA codes

Variables	Available in the PDR Checklist and/or as ICD 10-CA Codes
BC Health Service Delivery Area (resident)	Grouped into the following categories: • BC Resident • All other categories (excluded)
Number of births	Grouped into the following categories: • Singleton • All other categories (excluded)
Maternal diseases of the circulatory system and blood/blood forming organs	Codes beginning with: O99.1 Other disease of the blood and blood-forming organs and certain disorders involving the immune mechanism complicating pregnancy O99.4 Disease of the circulatory system complicating pregnancy O99.8 Other specified disease and conditions complicating pregnancy, childbirth and the puerperium
Pre-existing hypertension complicating pregnancy, hypertensive heart disease, hypertension secondary to renal disease	Codes beginning with: O10.1 Pre-existing hypertensive heart disease complicating pregnancy, childbirth, and the puerperium O10.2 Pre-existing hypertensive renal disease complicating pregnancy, childbirth and the puerperium O10.3 Pre-existing hypertensive heart and renal disease complicating pregnancy, childbirth and the puerperium O10.4 Pre-existing secondary hypertension complicating pregnancy, childbirth and the puerperium O10.9 Unspecified pre-existing hypertension complicating pregnancy, childbirth and the puerperium
Antihypertensive drugs, hypertensive chronic renal disease, hypertension due to other causes	Grouped into the following categories: • Yes (excluded) • No
Diabetes mellitus (insulin dependent), diabetes mellitus (non-insulin dependent)	Grouped into the following categories: • Yes (excluded) • No Codes beginning with: O24.5 Pre-existing type 1 diabetes mellitus in pregnancy O24.6 Pre-existing type 2 diabetes mellitus in pregnancy O24.7 Pre-existing diabetes mellitus of other or unspecified type in pregnancy

Liver disorders	Codes beginning with: O26.6 Liver disorders in pregnancy, childbirth and the puerperium
Tuberculosis, malaria	Codes beginning with: O98.0 Tuberculosis complicating pregnancy, childbirth and the puerperium O98.6 Protozoal diseases complicating pregnancy, childbirth and the puerperium
Number of previous pre-term deliveries	Grouped into the following categories: • ≤1 • >1 (excluded)
Previous cesarean deliveries	Grouped into the following categories: • ≤2 • >2 (excluded)
Number of spontaneous abortions	Grouped into the following categories: • ≤2 • >2 (excluded)
Pre-eclampsia, eclampsia, or either superimposed on pre-existing hypertension	Codes beginning with: O11 Pre-existing hypertensive disorder with superimposed proteinuria O14 Gestational hypertension with significant proteinuria O15 Eclampsia O16 Unspecified maternal hypertension
Hemorrhage from placenta previa	Codes beginning with: O44.1 Placenta praevia with haemorrhage
Rh immunoglobulin given or isoimmunization	Grouped into the following categories: • Yes (excluded) • No Codes beginning with: O36.0 Maternal care for rhesus isoimmunization O36.1 Maternal care of other isoimmunization
Incompetent cervix	Codes beginning with: O34.3 Maternal care for cervical incompetence
Severe hyperemesis	O21.1 Hyperemesis gravidarum with metabolic disturbance
Maternal age	Grouped into the following categories: • ≥ 14 years • < 14 years (excluded)
Delivery date/Infant birth date	Grouped into the following categories: • 1 Jan. 2005 to 31 Dec. 2012 • All other categories (excluded)
Variables	**Codes available in the MSP Payment Information File**
General practitioner routine antenatal visit	Claim specialty code "General Practice" and fee item code: • 14090 prenatal visit complete exam or

	• 14091 prenatal visit subsequent exam or • 04717 prenatal office visit complex obstetrical patient
Obstetrician routine antenatal visit	Claim specialty code "Obstetrician" and fee item code: • 14090 prenatal visit complete exam or • 14091 prenatal visit subsequent exam or • 04717 prenatal office visit complex obstetrical patient
Full or partial trimester of midwifery care	Fee item code: • 36010 midwife phase 1 (1rst trimester) total care • 36014 midwife phase 1 (1rst trimester) trans. to other 40% • 36016 midwife phase 1 (1rst trimester) trans. to other 60% • 36020 midwife phase 2 (2nd trimester) total care • 36024 midwife phase 2 (2nd trimester) trans. to other 40% • 36026 midwife phase 2 (2nd trimester) trans. to other 60% • 36030 midwife phase 3 (3rd trimester) total care • 36034 midwife phase 3 (3rd trimester) trans. to other 40% • 36036 midwife Phase 3 (3rd trimester) trans. to other 60%
MSP regular premium subsidy assistance	Subsidy code: • A (100%), B (80%), F (60%), G (40%), H (100% paid by social services)

APPENDIX B: Covariate description, data source, and ICD 10-CA codes

Variable	Description	PDR Checklist or ICD 10-CA Codes	Data Source
Maternal age	Age at date of delivery	Grouped into the following categories: • 14-19 • 20-24 • 25-29 • 30-34 • 35-39 • ≥ 40	PDR
Parity		Grouped into the following categories: • Nulliparous • Multiparous	PDR
Medical risk	Maternal disease of the respiratory or digestive system, and endocrine, nutritional, or metabolic disease	O99.5 Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium O99.6 Disease of the digestive system complicating pregnancy, childbirth and the puerperium O99.2 Endocrine, nutritional and metabolic disease complicating pregnancy, childbirth and the puerperium	PDR
Prior obstetric risk	Has had at least one of the following conditions in past pregnancy: neonatal death, stillbirth, infant with major congenital anomaly, or 1 preterm delivery	Grouped into the following categories: • Yes • No	PDR
Mental disorder or illness	Anxiety, depression, bipolar, postpartum depression, other and unknown mental disorders	Grouped into the following categories: • Yes • No	PDR

		Codes beginning with: F20 Paranoid schizophrenia F21 Schizotypal disorder F22 Delusional disorders F23 Brief psychotic disorder F24 Shared psychotic disorder F25 Schizoaffective disorder F28 Other psychotic disorder not due to a substance or known physiological condition F29 Unspecified psychosis not due to a substance or known physiological condition F30 Manic episode F31 Biopolar disorder F32 Major depressive disorder, single episode F33 Major depressive disorder, recurrent F34 Persistent mood [affective] disorders F39 Unspecified mood [affective] disorder F40 Phobic anxiety disorders F41 Anxiety disorder F42 Obsessive-compulsive disorder F43 Acute stress reaction O99.3 Mental disorders and disease of the nervous system complicating pregnancy, childbirth and the puerperium	
Receiving social assistance	Regular MSP subsidy assistance paid for by the Ministry of Employment and Income Assistance	Grouped into the following categories: • MSP subsidy assistance code H (100% subsidy) • All other categories (excluded)	MSP Payment Information File
Pre-pregnancy BMI	Ratio of a women's pre-pregnancy weight (kg) to height (m)	Grouped into the following categories: • Underweight (<18.5) • Normal (18.5-24.9) • Overweight (25-29.9) • Obese (≥ 30) • Unknown	PDR
Smoking status		Grouped into the following categories: • Never • Former • Current • Unknown	PDR

Substance use	Heroin/opioids, cocaine, methadone, solvents, prescription, marijuana, other, unknown drugs	Grouped into the following categories: • Yes • No or blank Codes beginning with: F11 Opioid dependence, abuse, use F12 Cannabis dependence, abuse, use F13 Sedative, hypnotic or anxiolytic dependence, abuse, use F14 Cocaine dependence, abuse, use F15 Other stimulant dependence, abuse, use F16 Hallucinogen dependence, abuse, use F18 Inhalant dependence, abuse, use F19 Other psychoactive substance dependence, abuse, use	PDR
Alcohol use	Alcohol during pregnancy identified as a risk by care provider	Grouped into the following categories: • Yes • No or blank Codes beginning with: F10 Alcohol dependence, abuse, use with alcohol-induced disorder	PDR
Antepartum morbidity	Hypertension (≥ 140/90) during pregnancy, pregnancy induced hypertension, gestational diabetes insulin dependent, non-insulin dependent, IUGR identified as a risk during the antenatal period, antepartum hemorrhage ≥ 20 weeks	Grouped into the following categories: • Yes • No Codes beginning with: O13 Gestational hypertension w/o significant proteinuria O24.8 Diabetes mellitus arising in pregnancy (gestational) O99.0 Anemia complicating pregnancy, childbirth and the puerperium O99.0 Maternal care for restricted fetal growth O98.4 Viral hepatitis complicating pregnancy, childbirth and the puerperium O98.5 Other viral diseases complicating pregnancy, childbirth and the puerperium O98.8 Other maternal infectious and parasitic disease complicating pregnancy, childbirth and the puerperium O98.9 Unspecified maternal infectious or parasitic disease complicating pregnancy, childbirth and the puerperium O44.0 Placenta previa specified as without	PDR

		haemorrhage O40 Polyhydramnios O41 Oligohydramnios O98.1 Syphilis complicating pregnancy, childbirth and the puerperium O98.2 Gonorrhoea complicating pregnancy, childbirth and the puerperium O98.3 Other infections with a predominantly sexual mode of transmission complicating pregnancy, childbirth and the puerperium O98.7 Human immunodeficiency disease complicating pregnancy, childbirth and the puerperium O45 Premature separation of placenta	
Delivery Year		Grouped into the following categories: • 2005 • 2006 • 2007 • 2008 • 2009 • 2010 • 2011 • 2012	PDR
Neighbour-hood SEP	Assigned on the basis of residence, reflects the average single-person income in a geographical area populated by approximately 400-700 people	Grouped into the following categories: • High • Low/Medium	Population Data BC, Consolid-ation File
Urban/rural residence	Population estimates (2009) of LHAs	Grouped into the following categories: • Urban • Rural • Unknown	BC Stats
LHA socioecono-mic index	LHAs in BC ranked according to area-level socioeconomic status, based on six indicators: human economic hardship, crime concerns, health problems,	Grouped into the following categories: • High • Medium • Low • Unknown	BC Stats and a number of social ministries[a]

	education concerns, children at risk, and youth at risk		
LHA income inequality	LHAs in BC ranked according to area-level income inequality	Grouped into the following categories: • High • Medium • Low • Unknown	BC Stats
Northern residence	Residing in the Northern Health Authority at delivery	Grouped into the following categories: • Yes • No	PDR
Gestational age at birth, in completed weeks	Calculated by algorithm incorporating last menstrual period, first ultrasound, infant exam, and maternal chart[b]	Used for coding small-for-gestational-age and preterm birth	PDR
Small-for-gestational-age birth	Based on admission weight in grams and infant's gestational age at birth in completed weeks (20 to 44 weeks)	Grouped according to Kierans' sex-specific birth weight standards[c]	PDR
Preterm birth	Infant's gestational age at birth in completed weeks	Grouped into the following categories: • 20 to 36 weeks • Other (excluded)	PDR

[a] BC Stats. Socio-economic indices: LHA indices reports. Human economic hardship: income inequality measure. 2013 [cited 2014 Nov 4]. From: http://www.bcstats.gov.bc.ca/StatisticsBySubject/SocialStatistics/SocioEconomicProfilesIndices/SocioEconomicIndices/LHAReports.aspx.

[b] Algorithm for the estimation of gestational age. Canadian Perinatal Surveillance System. Ottawa: Public Health Agency of Canada; 2010.

[c] Kierans W, Kramer M, Wilkins R, et al. Charting birth outcome in British Columbia: determinants of optimal health and ultimate risk--an expansion and update. Vancouver, BC: British Columbia Vital Statistics Agency; 2008 [cited 2017 Feb 16]. From: http://www.perinatalservicesbc.ca/Documents/Resources/HealthPromotion/BirthCharts/ChartingBirthOutcomeReport.pdf.

Appendix C: Adjusted odds ratios with and without control for antepartum morbidity

Antenatal Model	Without Control for Antepartum Morbidity OR (95% CI)	With Control for Antepartum Morbidity OR (95% CI)
Small-for-Gestational-Age Birth (< 10th percentile)[a]		
MW vs. GP	0·71 (0·62-0·82)	0·77 (0·67-0·89)
MW vs. OB	0·59 (0·50-0·69)	0·68 (0·59-0·80)
GP vs. OB	0·83 (0·76-0·91)	0·88 (0·80-0·96)
Preterm Birth (< 37 weeks gestation)[b]		
MW vs. GP	0·74 (0·63-0·86)	0·80 (0·69-0·93)
MW vs. OB	0·53 (0·45-0·62)	0·61 (0·51-0·71)
GP vs. OB	0·72 (0·65-0·79)	0·75 (0·69-0·83)
Low Birth Weight (<2500 g.)[c]		
MW vs. GP	0·66 (0·53-0·82)	0·80 (0·64-0·99)
MW vs. OB	0·43 (0·34-0·54)	0·58 (0·46-0·74)
GP vs. OB	0·65 (0·58-0·74)	0·73 (0·64-0·83)

All models adjusted for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status and substance use.

[a]Model also adjusted for mental illness, and LHA socioeconomic rank.

[b]Model also adjusted for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, mental illness, neighbourhood SEP, LHA socioeconomic rank, LHA income inequality, and northern residence.

[c]Model also adjusted for prior obstetric risk.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **On the title page and Methods section of the abstract**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Methods and Results sections of the abstract**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Introduction (pg. 6)**
Objectives	3	State specific objectives, including any prespecified hypotheses **Last sentence of the introduction (pg.6)**
Methods		
Study design	4	Present key elements of study design early in the paper **Methods (pgs. 6-7)**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Methods (pgs. 6-8)**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Methods (pgs. 9) and Appendix A**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **N/A**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Methods (pgs. 8, 11) and Appendix B**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Methods (pgs. 11) and Appendix B**
Bias	9	Describe any efforts to address potential sources of bias **Methods (pg. 12), Results (pg. 14), Discussion (pg. 20), and Appendix C**
Study size	10	Explain how the study size was arrived at **Methods (pg. 10)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Methods (pg. 11) and Appendix B**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **Methods (pgs. 10-11)**
		(*b*) Describe any methods used to examine subgroups and interactions **N/A**
		(*c*) Explain how missing data were addressed **Methods (pg. 12)**
		(*d*) If applicable, explain how loss to follow-up was addressed **N/A**
		(*e*) Describe any sensitivity analyses **Methods (pg. 12)**

Results		
Participants	13*	*(a)* Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Figure 1: Eligibility Flow Chart**
		(b) Give reasons for non-participation at each stage **Figure 1: Eligibility Flow Chart**
		(c) Consider use of a flow diagram **Figure 1: Eligibility Flow Chart**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Table 1 (pgs. 13-15) and Results (pgs. 16-17)**
		(b) Indicate number of participants with missing data for each variable of interest **Table 1 (pgs. 13-15)**
		(c) Summarise follow-up time (eg, average and total amount) **N/A**
Outcome data	15*	Report numbers of outcome events or summary measures over time **Table 2 and Results (pg. 16)**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **Results (pgs. 16-17), Methods (pgs. 11-12), and Table 2 (pg. 18)**
		(*b*) Report category boundaries when continuous variables were categorized **Table 1 (pgs. 13-15)**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **N/A**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **Results (pg. 17), Appendix C**
Discussion		
Key results	18	Summarise key results with reference to study objectives **First line of Discussion (pg. 19)**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Discussion (pgs.19-20), Appendix C**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Discussion (pgs. 21-23)**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Discussion (pg. 19)**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Acknowledgments (pg. 24), Disclaimers (pg. 24-25)**

*Give information separately for exposed and unexposed groups.

BMJ Open

Reduced prevalence of small-for-gestational-age and preterm birth for women of low socioeconomic position: a population-based cohort study comparing antenatal midwifery and physician models of care

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-022220.R1
Article Type:	Research
Date Submitted by the Author:	05-Jun-2018
Complete List of Authors:	McRae, Daphne; University of British Columbia, School of Population and Public Health Janssen, Patricia; University of British Columbia, School of Population and Public Health Vedam, Saraswathi; University of British Columbia, Birth Place Lab, Department of Family Practice Mayhew, Maureen; University of British Columbia, School of Population and Public Health Mpofu, Deborah; University of Saskatchewan, Dept. of Community Health and Epidemiology; Saskatoon Health Region, Saskatoon City Hospital Teucher, Ulrich; University of Saskatchewan, Dept. of Psychology Muhajarine, Nazeem; University of Saskatchewan, Dept. of Community Health and Epidemiology
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Health services research, Public health
Keywords:	midwifery, socioeconomic status, birth outcomes, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Fetal medicine < OBSTETRICS, Maternal medicine < OBSTETRICS

Reduced prevalence of small-for-gestational-age and preterm birth for women of low socioeconomic position: a population-based cohort study comparing antenatal midwifery and physician models of care

Correspondence to:|
Daphne McRae
School of Population and Public Health,
University of British Columbia
2206 E Mall, Vancouver BC Canada V6T 1Z3
Ph: +1 604-794-7729 Fax : +1 604-822-0640
daphne.mcrae@ubc.ca

Patricia A. Janssen
School of Population and Public Health,
University of British Columbia
2206 East Mall Vancouver BC Canada V6T 1Z3

Saraswathi Vedam
Birth Place Lab, Dept. of Family Practice
University of British Columbia
Suite 304 - 5950 University Boulevard Vancouver BC Canada V6T 1Z3

Maureen Mayhew
School of Population and Public Health
University of British Columbia
2206 East Mall Vancouver BC Canada V6T 1Z3

Deborah Mpofu
Saskatoon City Hospital
Saskatoon Health Region
701 Queen Street, Saskatoon SK S7K 0M7
and
Dept. of Community Health and Epidemiology
University of Saskatchewan
Box 7 Health Science Building 107 Wiggins Road Saskatoon SK Canada S7N 5E5

Ulrich Teucher
Dept. of Psychology
University of Saskatchewan
9 Campus Drive Saskatoon SK Canada S7N 5A5

Nazeem Muhajarine
Dept. of Community Health and Epidemiology
University of Saskatchewan

Box 7 Health Science Building 107 Wiggins Road Saskatoon SK Canada S7N 5E5

Keywords: midwifery, socioeconomic status, birth outcomes, quality in health care, fetal medicine, maternal medicine

Word count: 4,574

ABSTRACT

Objective: Our aim was to investigate if antenatal midwifery care was associated with lower odds of small-for-gestational-age (SGA) birth, preterm birth (PTB), or low birth weight (LBW) compared to general practitioner (GP) or obstetrician (OB) models of care for women of low socioeconomic position.

Setting: This population level, retrospective cohort study used province-wide maternity, medical billing, and demographic data from British Columbia, Canada.

Participants: Our study included 57,872 pregnant women, with low socioeconomic position, who: were residents of British Columbia, Canada, carried a singleton fetus, had low to moderate medical/obstetric risk, delivered between 2005-2012, and received medical insurance premium assistance.

Primary and secondary outcome measures: We report rates, adjusted odds ratios (aOR), and 95% confidence intervals for the primary outcome, SGA birth (< the 10th percentile), and secondary outcomes, PTB (< 37 weeks completed gestation), and LBW (< 2,500 g.).

Results: Our sample included 4,705 midwifery patients, 45,114 GP patients, and 8,053 OB patients. Odds of SGA birth were reduced for patients receiving antenatal midwifery vs. GP (aOR 0·71, 95% CI: 0·62-0·82) or OB care (aOR 0·59, 95% CI: 0·50-0·69). Odds of PTB were lower for antenatal midwifery vs. GP (aOR 0·74, 95% CI: 0·63-0·86) or OB patients (aOR 0·53, 95% CI: 0·45-0·62). Odds of LBW were reduced for midwifery vs. GP (aOR 0·66, 95% CI: 0·53-0·82) or OB patients (aOR 0·43, 95% CI: 0·34-0·54).

Conclusion: Antenatal midwifery care in British Columbia, Canada was associated with lower odds of SGA birth, PTB, and LBW, for women of low socioeconomic position, compared to

physician models of care. Results support the development of policy to ensure antenatal midwifery care is available and accessible for women of low socioeconomic position. Future research is needed to determine the underlying mechanisms linking midwifery care to better birth outcomes for women of low socioeconomic position.

Strengths and limitations of this study

- This large, population-level cohort study (n=57,872) represented the majority of pregnant women with low socioeconomic position in British Columbia, Canada (2005-2012)
- The rigorous modelling approach controlled for correlation in outcomes at a family and community level
- Findings are generalizable to other high resource settings which offer similar, publicly funded midwifery services
- Limited by self-selection of care provider which could have introduced differences between cohorts in social/health risks undocumented in the maternity record
- Included a post hoc analysis controlling for antepartum morbidity to assess the magnitude of self-selection bias

INTRODUCTION

As established in the literature, women of low socioeconomic position (SEP) are more susceptible to poor infant birth outcomes compared to women of higher SEP.[1] In response to this inequity, researchers have sought to determine if antenatal midwifery care could minimize the risk of adverse newborn outcomes for women of low SEP. In a 2016 scoping review of randomized trials and observational studies from high resource countries (1990 to 2015), comparing antenatal midwifery versus physician-led care for women of low SEP,[2] results indicated lower risk of preterm birth (PTB),[3] low birth weight (LBW)[4], and/or very low birth weight (VLBW)[4,5] for midwives' patients in some studies (or subpopulations within studies), yet other studies indicated no significant difference in outcomes by provider-type.[6-8] Almost all of these studies were limited by non-representative sampling,[3,6,7] inadequate study power,[6,8-10] and/or failure to control for confounders.[4,6] All but one study[6] were conducted in the United States. Addressing these limitations, we conducted a large, population level study among women of low SEP with low to moderate medical/obstetric risk to investigate if antenatal midwifery care was associated with lower odds of small-for-gestational-age (SGA) birth, PTB, or LBW compared to general practitioner (GP) or obstetrician (OB) models of care.

METHODS

Study design

Using a retrospective cohort design we examined the association between antenatal models of care and odds of SGA birth, PTB, or LBW among women of low SEP with low to moderate medical/obstetric risk. In British Columbia (BC), women with low to moderate perinatal risk are eligible for midwifery care. Model of care was ascertained using practitioners' antenatal service

billing records. Women may have had an initial appointment with a GP if this was their preferred type of maternity provider, or because they were waitlisted for midwifery care, required an OB referral, or were unaware of the options for OB or midwifery care until the first prenatal appointment. Therefore, we did not classify patients' model of care by initial practitioner contact (intent-to-treat). Rather, patients were classified according to the type of practitioner providing all of their routine antenatal care, with allowance for one routine visit with another practitioner-type. Aside from excluding all patients with high perinatal risk, patients with low to moderate perinatal risk and two or more practitioner-types providing routine antenatal care were excluded from the study. None of the GP or midwifery patients included in the study had antenatal conditions recorded in the perinatal record requiring transfer to an OB, nor did any OB patients have antenatal conditions recorded in the record rendering them ineligible for midwifery care.

In British Columbia, GPs and OBs are compensated by the Ministry of Health for each antenatal visit whereas midwives are compensated according to partial or full trimester of care, regardless of the number of antenatal visits provided (see Table 1). Antenatal care with a GP was defined as greater than or equal to three routine antenatal visits with a GP, and less than or equal to one routine antenatal visit with an OB, or less than or equal to one partial trimester of midwifery care. Antenatal care with an OB was operationalized as greater than or equal to three routine antenatal visits with an OB, and less than or equal to one routine antenatal visit with a GP, or less than or equal to one partial trimester of midwifery care. Antenatal midwifery care was operationalized as greater than or equal to two partial or full trimesters of midwifery care (equivalent to a *minimum* exposure of three routine antenatal physician visits), and less than or equal to one routine GP or OB antenatal visit. Obstetrician consultations were not included as routine antenatal visits.

Table 1: Characteristics of antenatal models of care in British Columbia

	TOTAL BC POPULATION		
	Antenatal Care Provider		
	Midwife	**General Practitioner**	**Obstetrician**
Provider involved in ANC[a]	22.4%	Unavailable	Unavailable
Delivery provider[b]	14.0%	32.5%	51.2%
Patient risk-level	Low to moderate[c]	Low to moderate	Low, moderate, & high
Access to services	Self-referral	Self-referral	Referral by a MW or GP on request or by indication, or self-referral for a repeat pregnancy
Cost of services for BC residents[d]	100% coverage by provincial medical insurance	100% coverage by provincial medical insurance	100% coverage by provincial medical insurance
Practitioner's billing method	Per course of care, MWs can bill for full care (100%) or partial care (40% or 60%) per trimester, depending on patient transfer	Per ANC visit	Per ANC visit
	STUDY POPULATION[e]		
Average no. of routine ANC visits	10.9	8.5	9.0
Delivery provider			
MW	77.6%	0.5%	0.2%
GP	2.5%	68.3%	3.1%
OB	18.2%	26.1%	93.9%
Other	1.7%	5.0%	2.8%

Definitions: MW midwife, ANC antenatal care

[a] any involvement in ANC (2014/15)[11]

[b] may differ from the ANC provider, preliminary data (2016/17)[12]

[c] based on guidelines produced by the College of Midwives of BC[13]

[d] residents must be eligible for provincial medical insurance (i.e. Canadian citizens or permanent residents)

[e] study population consisted of low SEP women with low to moderate perinatal risk, 2005-2012, this data was unavailable for the total BC population

Ethics approval for this study was granted from the University of Saskatchewan, Biomedical Research Ethics Board (Reg. No. #1 00001471, #2 00008358) and the University of British Columbia, Children's and Women's Health Center of BC Research Ethics Board (Reg. No. H14-01629).

Setting

In BC women select their preferred type of maternity caregiver depending on practitioner availability and as appropriate to their need for specialist care. In rare instances women may have planned, shared-care between a small pool of midwives and GPs. Midwifery care in the Canadian context is equivalent to caseload midwifery care as it is practiced in Australia, the UK, and other European countries. Midwives provide holistic, continuity of care in which a midwife, or a small pool of midwives, known to a women is/are available on-call 24 hours a day.[14] The midwifery model is relationship-based with antenatal appointments lasting 30 to 60 minutes on average[15] to facilitate counselling, education, emotional support, and informed choice.[14] When a midwifery patient has moderate perinatal risk, as outlined in the BC College of Midwives' guidelines,[13] midwives are required to consult with a physician (generally an OB) and if high-risk complications arise they will recommend a transfer to OB care.

While many GPs and some OBs function in a continuity of care, relationship-based model, the volume of need and fee-for-service funding model for physicians leads to shorter antenatal visits. Within the midwifery model, fees are all inclusive based on care and annual caseloads are limited allowing for longer antenatal visits on average.[14] All three types of providers follow the same schedule of antenatal visits.

Outcomes

Our outcome data for this study was obtained from the BC Perinatal Data Registry (PDR).[16] Registry data was abstracted from hospital and home birth records. As well, International Statistical Classification of Diseases (ICD-10-CA) codes were imported to the PDR from the Canadian Institutes of Health Information Discharge Abstract Database. The PDR captures approximately 99% of all BC births with validation studies reporting a 97% accuracy rate over all data fields.[17]

The primary outcome variable was SGA birth (< 10th percentile) according to Kierans and colleagues' sex-specific birth weight charts.[18] Secondary outcomes included PTB (< 37 weeks completed gestation), and LBW (< 2,500 g.). LBW may be attributable to PTB, intrauterine growth restriction, or both and is reported here to facilitate comparison with other studies.

Study sample

Our study sample included women who: were residents of BC, received antenatal midwifery, GP or OB care, carried a singleton fetus, had low to moderate medical/obstetric risk, delivered between 1 January 2005 and 31 December 2012, received medical insurance premium assistance, and were not registered Status Indian. All women were classified as having low to moderate medical and obstetric risk if they were eligible for midwifery care throughout the antenatal period according to guidelines produced by the College of Midwives of BC[13] and expert advice from our clinical team members. Conditions rendering women ineligible for midwifery care included diseases of the blood, blood forming organs or of the circulatory system, pre-existing hypertension or diabetes, liver disorders, tuberculosis, or malaria, as recorded in the maternity

record, history of more than one PTB, more than two caesarean section deliveries, or more than two spontaneous abortions (prior to 20 weeks completed gestation), or in the current pregnancy pre-eclampsia/eclampsia, placenta previa with hemorrhage, isoimmunisation, incompetent cervix, hyperemesis gravidarum with metabolic disturbance, or age less than 14 years. (See Appendix A for a complete description of inclusion/exclusion variables and ICD 10-CA codes.)

Because the key indicator used to assess low SEP, medical insurance premium assistance, was not available for Status women (they had their insurance premiums paid through Health Canada) they were excluded from the study. We operationalized low SEP as receipt of BC Medical Services Plan (MSP) regular premium subsidy assistance during the year of delivery.[19] Eligibility for this assistance is based on family, net income ceiling exclusive of federal or provincial childcare or disability benefits. During the study period the ceiling ranged from $24,000 to $30,000 for a family of three depending on the year of receipt.[19] This is comparable to Statistics Canada's before-tax, low income cut-off for a family of three ($23,358 to $33,933 as of 2008),which is a standard measure of poverty.[20]

Sample Size Estimates

During the study period women living in the poorest neighbourhood income quintiles in Canada experienced a 9·9% prevalence of SGA.[21] To detect an absolute difference in prevalence of 3% (similar to estimates of prevalence in the general population) from a baseline of 9·9% we required a minimum sample of 1,249 MW patients, 2,497 OB patients, and 4,861 GP patients. Type I error was set at p=0·025 two sided, and type II error set at 0·20. We estimated 16·2% of the total BC population received MSP premium assistance,[22] equivalent to 4,154 midwifery

patients and 36,255 physician patients during the study period, excluding those who would not meet our criteria for low to moderate obstetrical risk. Sample size calculations were conducted using OpenEpi 3.01.

Statistical Analyses

To assess the association of model of care and SGA, PTB, and LBW, we developed logistic regression models using a Generalized Estimating Equation approach.[23] This method allowed for adjustment of variance estimates to accommodate potential correlation for women delivering multiple infants during the study period and for clustering of effects by community.[23] Differing correlation structures were specified and compared using the Quasi-Likelihood Under the Independence model Criteria (QIC) to determine the most appropriate correlation structure (the smaller the QIC the better the structure's fit).[23] Binomial distributions were specified and models fitted with an exchangeable correlation structure (in which observations from the same cluster are assumed to be equally correlated) using logit link functions.[23]

We identified potential confounders, tested in our model, from the literature and based on our clinical experience. Variables analyzed from the PDR included maternal age, parity, medical risk, prior obstetric risk, pre-pregnancy BMI, infant sex, delivery year, smoking status, substance use, alcohol use, mental illness, and northern residence. (See Appendix B for a complete list of covariate descriptions, data sources, and ICD 10-CA codes.) From the Province of BC Statistics Division (BC Stats) we obtained socioeconomic rankings and income inequality rankings for each Local Health Area (LHA)—89 geographic and health administrative regions in BC that aggregate to larger Health Authorities.[24] Income inequality rankings were based on the

proportion of each LHA's total income from all households earning less than the median income compared to each LHA's total income from all households. In an entirely equitable LHA the poorest half of the households would garner 50% of the total income.[24] We tested this variable as a potential confounder because it has been hypothesized that residence in a high income inequality area may increase the risk of poor self-concept potentially leading to lower commitment to pregnancy and unhealthy lifestyle choices.[25] From the BC Ministry of Health we received data on women's neighbourhood income quintile, depending on residential postal code at delivery,[26] and receipt of social assistance[19]—public financial assistance granted to low income individuals.

In logistic regression univariate analyses we identified variables that had Wald chi-square values of $p < 0{\cdot}25$ and retained these for our initial multivariable models.[27] For the final variable selection we used a manual, backward elimination approach. Variables with a Wald chi-square p-value $\geq 0{\cdot}05$ were excluded from each multivariable model one at a time, beginning with the variable having the largest p-value.[27] After suspected confounders were removed from a model, coefficient estimates from models with and without the variable were examined to determine if the exclusion produced a greater than 20% change in any coefficient in the model. If this magnitude of change was detected, indicating a meaningful adjustment to (an)other variable(s), the eliminated variable was returned to the model.[27, p92] This process was repeated until only variables meeting the criteria or those of clinical significance remained in the model. For births with no missing information we report unadjusted and adjusted odds ratios and 95% confidence intervals for SGA, PTB, and LBW by model of care.

Lastly, we investigated residual confounding potentially arising from self-selection bias associated with pre-existing morbidity. If, for example, women chose OB care because of prior health conditions which were not documented in the PDR, then the OB cohort could be comprised of systematically higher-risk patients. To assess the potential effect of these conditions on our final models we conducted sensitivity analyses adjusting our final models for select antepartum morbidities (see definition in Table 2). We also conducted sensitivity analyses excluding women with any known pre-existing conditions, to assess the impact of differing rates of moderate perinatal risk between cohorts on effect estimates. SAS Enterprise 7·1 (SAS Institute, Cary, NC, USA) was used for data analysis.

Patient Involvement

Patients were not involved in the development of the research question or study design. However, Canadian studies have shown that women of low SEP report more respectful care and greater autonomy in decision-making within the midwifery model compared to physician-led models of care.[15,28] Results of this study may be of particular interest to women of low SEP who have a preference for midwifery care.

RESULTS

There were 4,705 midwifery, 45,114 GP, and 8,053 OB pregnancies included in the study (Figure 1). Both midwives' and OBs' patients were, on average, older than GPs' patients, more likely to be multiparous, non-smokers, and residing in urban areas (Table 2). Although all women were of low income at a family-level, a greater proportion of midwifery patients lived in wealthier towns/districts (LHAs) and neighbourhoods compared to GP or OB patients. This may

be a reflection of health policy influencing the distribution of midwifery availability across the province. Midwifery care may be more available in desirable (i.e. wealthier, southern, urban) areas as midwives are able to choose where they will open a practice and they are not eligible for the same financial incentives offered to rural and remote physicians.[29]

Table 2: Frequencies and proportions of maternal characteristics by antenatal model of care, British Columbia, 2005-2012 (n=57,872)

Characteristics	Antenatal Model of Care		
	MW n=4,705 (%)	GP n=45,114 (%)	OB n=8,053 (%)
Age (yrs.)			
14-19	155 (3·29)	4,697 (10·41)	338 (4·20)
20-24	893 (18·98)	14,789 (32·78)	1,447 (17·97)
25-29	1,619 (34·41)	13,161 (29·17)	2,303 (28·60)
30-34	1,362 (28·95)	7,966 (17·66)	2,113 (26·24)
35-39	573 (12·18)	3,730 (8·27)	1,387 (17·22)
≥40	103 (2·19)	771 (1·71)	465 (5·77)
Parity[a]			
Nullipara	2,177 (46·27)	23,141 (51·30)	3,617 (44·91)
Multipara	2,528 (53·73)	21,972 (48·70)	4,435 (55·07)
Medical risk[b,c]	14 (0·30)	414 (0·92)	132 (1·64)
Prior obstetric risk[b,d]	124 (2·64)	1,669 (3·70)	478 (5·94)
Mental illness[b,e]	1,020 (21·68)	5,146 (11·41)	610 (7·57)
Receiving social assistance[b]	310 (6·59)	5,833 (12·93)	814 (10·11)
Pre-pregnancy Body Mass Index (BMI)[f]			
Underweight	229 (4·87)	2,300 (5·10)	519 (6·44)
Normal	2,612 (55·52)	16,777 (37·19)	2,990 (37·13)
Overweight	689 (14·64)	5,829 (12·92)	877 (10·89)
Obese	335 (7·12)	3,792 (8·41)	479 (5·95)
Unknown	840 (17·85)	16,416 (36·39)	3,188 (39·59)
Smoking Status			
Never	992 (21·08)	6,666 (14·78)	1,868 (23·20)
Former	690 (14·67)	5,028 (11·15)	434 (5·39)
Current	471 (10·01)	9,910 (21·97)	800 (9·93)
Unknown	2,552 (54·24)	23,510 (52·11)	4,951 (61·48)
Substance use in pregnancy[b,g]	179 (3·80)	3,273 (7·25)	302 (3·75)
Alcohol identified as a risk[b]	57 (1·21)	1,109 (2·46)	63 (0·78)
Utilization of prenatal care[h]			
Intense	98 (2·08)	304 (0·67)	60 (0·75)
Adequate	1,420 (30·18)	6,851 (15·19)	902 (11·20)
Intermediate	1,927 (40·96)	19,929 (44·17)	2,601 (32·30)
Inadequate	273 (5·80)	6,986 (15·49)	980 (12·17)
Unknown	987 (20·98)	11,044 (24·48)	3,510 (43·59)
Antepartum morbidity[b,i]	349 (7·42)	6,843 (15·17)	1,955 (24·28)
Delivery year			
2005	307 (6·52)	5,772 (12·79)	955 (11·86)
2006	437 (9·29)	6,028 (13·36)	1,002 (12·44)
2007	471 (10·01)	6,133 (13·59)	1,074 (13·34)

2008	512 (10·88)	5,892 (13·06)	977 (12·13)
2009	606 (12·88)	5,640 (12·50)	910 (11·30)
2010	694 (14·75)	5,371 (11·91)	1,000 (12·42)
2011	796 (16·92)	5,337 (11·83)	1,014 (12·59)
2012	882 (18·75)	4,941 (10·95)	1,121 (13·92)
Neighbourhood SEP[j]			
High	624 (13·26)	4,984 (11·05)	646 (8·02)
Low/Medium	4,081 (86·74)	40,130 (88·95)	7,407 (91·98)
Local Health Area (LHA) Population Demographic[k]			
Urban	4,548 (96·66)	42,489 (94·18)	7,889 (97·96)
Rural	145 (3·08)	2,576 (5·71)	145 (1·80)
Unknown	12 (0·26)	49 (0·11)	19 (0·24)
LHA Socioeconomic Rank[l]			
High (Best)	2,638 (56·07)	13,287 (29·45)	4,043 (50·20)
Medium	1,472 (31·29)	22,011 (48·79)	3,197 (39·70)
Low	582 (12·37)	9,710 (21·52)	739 (9·18)
Unknown	13 (0·28)	106 (0·23)	74 (0·92)
LHA Income Inequality Rank[m]			
High (Worst)	1,667 (35·43)	10,635 (23·57)	4,177 (51·87)
Medium	2,326 (49·44)	25,544 (56·62)	3,311 (41·12)
Low	699 (14·86)	8,841 (19·60)	530 (6·58)
Unknown	13 (0·28)	94 (0·21)	35 (0·43)
Northern Residence[b,n]	136 (2·89)	6,032 (13·37)	291 (3·61)

All characteristics examined differed significantly by model of care (X^2 $p < 0·0001$)

[a] missing cases amount to 5 or less

[b] values represent cases classified as "Yes", the remainder of the cases were classified as "No", "Unknown", or were undocumented

[c] included maternal disease of the respiratory or digestive system, and endocrine, nutritional, or metabolic disease

[d] included women with at least one of the following conditions in past pregnancy: infant with major congenital anomaly, neonatal death, stillbirth, or one preterm delivery

[e] included any of the following diagnoses prior to, or during the current pregnancy: anxiety disorder, depression, postpartum depression, bipolar disorder, other/unknown (including schizophrenic, mood, and psychotic disorders)

[f] classified according to Health Canada's guidelines[30]

[g] heroin/opioids, cocaine, methadone, solvents, marijuana, or other/unknown drugs used at any time during pregnancy, prescription or other drug use identified as a risk at any time during pregnancy

[h] classifications based on Kotelchuck's Adequacy of Prenatal Care Utilization Index[31]

[i] included pregnancy induced hypertension, gestational diabetes (whether or not insulin dependent), anemia, intrauterine growth restriction, viral disease, infection and parasitic disease, placenta previa without hemorrhage, polyhydramnios or oligohydramnios, antepartum hemorrhage $\geq$ 20 weeks, sexually transmitted infection or HIV, or premature separation of the placenta

[J] neighbourhood income quintiles were classified as low/medium (quintiles 1-4) vs. high (quintile 5)[26]
[k] rural LHAs had a population < 10,000 people
[l] calculated by BC Stats, based on a range of social determinants of health reflecting area-level economic and social processes, and policy decisions[24]
[m] calculated by BC Stats[24]
[n] at the time of delivery, normal residence in BC's Northern Health Authority

Midwifery and OB patients less frequently reported alcohol or substance use during pregnancy compared to GP patients. A higher proportion of GP and OB patients had moderate medical risk and prior obstetric risk than midwifery patients, though midwifery patients had higher prevalence of reported mental illness during or prior to pregnancy (Table 2). Midwife and GP patients had higher rates of overweight or obese BMI than OB patients. Midwives' patients also had higher prevalence of adequate attendance at prenatal care compared to physicians' patients.

Of all infants in our study, 7·09% were SGA, 6·50% were PTB, and 3·32% were LBW (Table 3). On average there was a significant reduction in unadjusted odds of SGA for midwifery vs. GP patients (OR 0·67, 95% CI: 0·58 to 0·77) and midwifery vs. OB patients (OR 0·55, 95% CI: 0·47 to 0·64). GP vs. OB patients were also less likely to have a SGA infant (OR 0·81, 95% CI: 0·75 to 0·89). When controlling for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status, substance use, mental illness, and LHA socioeconomic rank, women receiving antenatal care from midwives vs. GPs had lower odds of having a SGA infant (aOR 0·71, 95% CI: 0·62 to 0·82) (Table 3). Midwifery vs. GP patients also had lower adjusted odds of SGA birth (aOR 0·59, 95% CI: 0·50 to 0·69). GP antenatal care was likewise associated with lower adjusted odds of SGA birth compared to OB care (aOR 0·83, 95% CI: 0·76 to 0·91).

Table 3: Frequencies, proportions and adjusted odds ratios for small-for-gestational-age birth, preterm birth, and low birth weight by antenatal model of care, British Columbia, 2005-2012

	MW n= 4,705	GP n= 45,114	OB n= 8,053	MW vs. GP	MW vs. OB	GP vs. OB
	n(%)	n(%)	n(%)	OR (95% CI)	OR (95% CI)	OR (95% CI)
SGA[a]	227/4,695 (4·83)	3,179/45,002 (7·06)	689/ 8,025 (8·59)	0·71 (0·62-0·82)	0·59 (0·50-0·69)	0·83 (0·76-0·91)
PTB[b]	207/4,702 (4·40)	2,848/45,028 (6·32)	698/8,033 (8·69)	0·74 (0·63-0·86)	0·53 (0·45-0·62)	0·72 (0·65-0·79)
LBW[c]	91/4,704 (1·93)	1,438/45,091 (3·19)	393/8,046 (4·88)	0·66 (0·53-0·82)	0·43 (0·34-0·54)	0·65 (0·58-0·74)

All models adjusted for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status and substance use.
[a]Model also adjusted for mental illness, and LHA socioeconomic rank. Odds ratios based on 4,095 births with SGA and 57,722 total births with no missing information for this analysis.
[b]Model also adjusted for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, mental illness, neighbourhood SEP, LHA socioeconomic rank, LHA income inequality, and northern residence. Odds ratios based on 3,753 PTB births and 57,763 total births with no missing information for this analysis.
[c]Model also adjusted for prior obstetric risk. Odds ratios based on 1,922 births with LBW and 57,841 total births with no missing information for this analysis.

The unadjusted odds of PTB were lower for woman receiving antenatal care from midwives vs. GPs (OR 0·68, 95% CI: 0·59 to 0·79) and midwives vs. OBs (OR 0·49, 95% CI: 0·41 to 0·57). GP vs. OB patients also had lower unadjusted odds of PTB (OR 0·71, 95% CI: 0·65 to 0·78). When adjusting the PTB model for the same variables as the SGA model, as well as for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, neighbourhood SEP, LHA income inequality, and northern residence, odds of PTB remained statistically significantly lower for midwifery vs. GP care (aOR 0·74, 95% CI: 0·63 to 0·86) and midwifery vs. OB care (aOR 0·53, 95% CI: 0·45 to 0·62). On average, GP patients also had lower adjusted odds of PTB compared to OB patients (aOR 0·72, 95% CI: 0·65 to 0·79).

Women receiving antenatal midwifery care had lower unadjusted odds of LBW compared to those in the care of GPs (OR 0·60, 95% CI: 0·49 to 0·74) or OBs (OR 0·39, 95% CI: 0·31 to 0·50). GP vs. OB patients also had lower unadjusted odds of LBW (OR 0·65, 95% CI: 0·58 to 0·73). After adjustment for maternal age, parity, prior obstetric risk, pre-pregnancy BMI, infant sex, smoking status, and substance use, women in the care of midwives had lower odds of LBW compared to GP (aOR 0·66, 95% CI: 0·53 to 0·82) or OB patients (aOR 0·43, 95% CI: 0·34 to 0·54). GP patients also had lower adjusted odds of LBW compared to OB patients (aOR 0·65, 95% CI: 0·58 to 0·74).

When testing for residual confounding by controlling for select antepartum morbidities the associations between model of care and SGA, PTB, and LBW were attenuated but remained statistically significant (see Appendix C: Table 1). Sensitivity analyses excluding women with

prior medical risk or a history of obstetric risk (see Table 2 for definitions) produced results nearly identical to our final models (see Appendix C: Table 2).

DISCUSSION

Strengths and Weaknesses

Our study demonstrated a statistically significant reduction in odds of SGA, PTB, and LBW for infants born to women of low SEP receiving antenatal midwifery vs. physician-led care in BC, Canada. This study represented the majority of pregnant, low SEP women in BC during the study period, had adequate study power, and tested a wide range of individual and area-level potential confounders. In addition, GEE logistic regression modelling allowed us to account for correlation in outcomes at a family and community level, a more rigours modelling approach than the methods used in previous studies. As this was a large, population based study, findings are generalizable for other high resource countries which offer similar, publicly funded midwifery services.

Our study was limited by its observational design. As women have been shown to refuse randomization to retain choice in maternity care provision,[32] and because midwifery care is a newer, government-funded maternity care option in BC (since 1998) in growing demand, evidence for causality will need to be established by repeated observational studies with representative samples over time. This study was also limited by a lack of data on the use of universal, objective screening tools for alcohol/substance use and mental health conditions, and it did not include measures of severity. In addition, there was no data available on race/ethnicity, language, or culture, and we were not able to assess outcomes among women who were Status

Indians. It should also be noted that in some cases antenatal midwifery and GP care included discussion or consultation with OBs for complex cases, and included transfer of care to OBs during labour and delivery when indicated. Though unmeasured, the quality of collaboration between practitioners and the use of obstetric referral will have had an influence on the results.

Women in the study self-selected their care provider, therefore it is possible that those with higher perinatal risk (on the low to moderate risk spectrum) chose obstetrician care, creating a higher risk OB cohort. However, we did control for a wide range of known medical and obstetric risk factors when indicated, and overall the population had very low prevalence of known pre-existing risk (medical risk 0.97%, prior obstetric risk 3.92%). In addition, when we conducted two sensitivity analyses, controlling for antepartum morbidity (Appendix C: Table 1), and secondly excluding patients with prior medical or obstetric risk (Appendix C: Table 2), the main associations remained significant. Lastly, because women utilizing midwifery care in BC may need to be pro-active in ascertaining services early in pregnancy due to high demand, it is plausible that women who secured midwifery care were more knowledgeable about the health care system, more invested in their health, or had greater ability to pursue preferred health care services. These skills, attitudes, and values could have systematically differed between cohorts. Nonetheless, we did control for smoking, alcohol, and pre-pregnancy BMI, which may reflect women's attitudes, beliefs, and values during pregnancy, and this may have minimized self-selection bias.

Results in comparison with other studies

Our results for PTB coincide with a 2016 Cochrane review synthesizing the findings of eight randomized controlled trials (RCTs) testing midwifery-led continuity models of care vs. other

models, including midwifery-physician models and medical-led care. In this review, authors found a 24% reduction in risk of PTB, less than 37 weeks gestation, for midwifery patients (average risk ratio 0·76, 95% CI: 0·64 to 0·91, n=13,238).[33] This is comparable to our 26% reduction in odds of PTB, less than 37 weeks gestation, for midwifery vs. GP patients (aOR 0·74, 95% CI: 0·63 to 0·86, n=49,819). As recommended in the Cochrane review, our study specifically focused on vulnerable women. Observational studies with non-representative samples (a freestanding birth centre serving primarily low income African American women,[3] and an Australian, hospital-based cohort study restricted to women ≤ 21 years of age[34]) have also reported findings similar to ours. In a RCT for low SEP women who had high risk of delivering LBW infants, odds of VLBW was significantly lower among a subgroup of African American nurse-midwifery patients vs. OB patients (OR 0·35, 95% CI: 0·1 to 0·9).[5] However, there was no difference in odds of LBW or VLBW by practitioner-type in the overall sample. Additionally, in a retrospective cohort study[4] comparing outcomes of nurse-midwifery care to usual care for Medicaid recipients or uninsured patients residing in Westchester County, New York, nurse-midwifery patients had significantly lower risk of LBW and VLBW. Yet, in this study there was no adjustment for pre-existing health complications or perinatal risk which may have introduced bias.

Five other midwifery/physician studies involving women of low SEP have reported no significant differences in SGA or PTB by provider-type.[6-10] Almost all studies were limited by failure to control for pre-existing medical/obstetric risk[6] or inadequate power to detect clinically important differences between cohorts.[6,8-10] In one adequately powered, prospective cohort study (n=2,957)[7] comparing collaborative birth center care provided by midwives (with OB referral for

complications) vs. OB or OB resident care, no statistically significant differences were reported. This study, however, was conducted in the U.S. and comprised of 77% Hispanic women.

Experience of antenatal care across models

In our study, adequate antenatal care utilization may have been a mechanism linking midwifery care to reduced odds of SGA, PTB, and LBW. Midwives' patients had 2·3 times greater odds of adequately utilizing antenatal care compared to GPs' patients and 2·5 times greater odds compared to OBs' patients. As revealed in a 2009 qualitative meta-synthesis, antenatal care use by marginalized women is associated with their perception of their clinician's trustworthiness, cultural sensitivity, and respect for life experience.[35] Adequate use of antenatal care has been shown to protect against PTB, stillbirth, and neonatal and infant death.[36] If midwifery's relationship-based model of care encouraged antenatal care uptake, it may have indirectly affected prevalence of infant morbidity for women of low SEP.

Lack of patient trust may also have inhibited patient disclosure of compromising health conditions. Midwifery patients had higher prevalence of mental illness overall and for each category (i.e. depression, anxiety, bipolar disorder) compared to GP or OB patients. Midwives' patients had a 2·2 fold increase in odds of documented mental illness, compared to GPs' patients and a 3·4 fold increase compared to OBs' patients. In our study, prevalence of depression for midwifery patients approximated that reported in the literature. In a review of 16 antenatal and postnatal depression studies (n=35,419) which were published between 2000 and 2016, and mainly conducted in western Europe, researchers reported a mean antenatal depression prevalence of 17·2%.[37] In our study, data on depression was collected between 2008 to 2012.

The proportion of midwifery patients with depression prior to or during pregnancy was 18·8% in contrast to 12·8% for GP patients and 7·4% for OB patients.

Greater disclosure of sensitive information to midwives providing caseload midwifery care has been noted in other studies. In the Australian midwifery cohort study previously cited, young women receiving caseload midwifery care were significantly ($p < 0·01$) more likely to report a history of mental illness, illicit drug use, and involvement with the Department of Child Safety than those receiving standard maternity care.[34] Likewise, in a small retrospective cohort study (n=194) conducted in the U.K. researchers examined birth outcomes by caseload midwifery care to standard maternity care for women with vulnerabilities (i.e. experiencing "domestic violence, homelessness, mental health issues, substance and/or alcohol abuse").[38, p411] Women in the caseload midwifery cohort were statistically significantly more likely to receive a referral to psychiatric care and/or domestic violence or other support services which may be indicative of higher rates of disclosure among midwifery patients. Of note, in both of these studies patients in the caseload midwifery cohorts had either a higher mean number of antenatal appointments[38] or a lower percentage of inadequate prenatal utilization of care (< 5 visits).[34] This likely increased clinician-patient familiarity which is a component of trust shown to influence domestic abuse disclosure.[39]

In our study, odds of antepartum morbidity were lower for midwives' vs. physicians' patients providing another clue as to the mechanisms linking midwifery care to a reduction in prevalence of SGA, PTB, and LBW. Midwifery vs. GP patients had 59% lower odds of antepartum morbidity (see definition in Table 2), and midwifery vs. OB patients had 74% lower odds. When

controlling for antepartum morbidity odds of SGA, PTB, and LBW by model of care were attenuated but remained statistically significant (Appendix C: Table 1). This suggests that even if antepartum morbidity were related to baseline differences in health status (selection bias), this could only partially explain the lower odds of adverse infant birth outcomes for women in the care of midwives vs. physicians. It is plausible longer appointment times and a holistic approach to care may have made it possible for midwives to identify pre-morbid conditions (i.e. borderline hypertension or anemia) earlier in pregnancy and implement preventative measures before conditions progressed to antepartum morbidity.

Implications

Study findings indicate a need for policy which supports midwifery availability and accessibility for women of low SEP. This could include incentivizing midwifery outreach to vulnerable populations by compensating midwives for the extra time involved in caring for women with higher socioeconomic risk. It could also mean increasing the volume of midwives practicing in the province to meet current demand, and conducting targeted public awareness campaigns to educate low SEP women about the government-funded options available in maternity care. Future studies are needed to identify which attributes of midwifery care influence infant birth outcomes for women of low SEP and the mechanisms (i.e. physiological, psychological and/or behavioural) underlying this association. In our study midwifery care was associated with the lowest odds of adverse birth outcomes followed by GP, then OB care. Antenatal midwifery and GP practice may have greater similarity (with respect to continuity in care, provision of emotional support, and volume of medical intervention) than midwifery to OB care. Therefore, it

could be useful to analyze characteristics of practice common to midwifery and GP care but which differ from OB practice.

CONCLUSION

Our study demonstrated lower odds of SGA birth, PTB, and LBW for women of low SEP in BC who received antenatal midwifery vs. physician-led care. As this was a large, population based study with adequate study power and control for confounders, our results are generalizable to other high resource countries offering similar midwifery services. Results of this study support the development of policy to ensure antenatal midwifery care is available and accessible for women of low SEP. Further research is needed to determine the mechanisms linking antenatal midwifery care to better birth outcomes among women of low SEP.

ACKNOWLEDGMENTS

We thank Celeste Bickford for assistance in linking the Research Extracts and data preparation. DNM was supported by an Arthur Smyth Scholarship from the College of Medicine, and a PhD Scholarship from the Department of Community Health and Epidemiology, University of Saskatchewan, SK, Canada. PAJ is supported by a Senior Scholar salary award from the BC Children's Hospital Research Institute, Vancouver, BC, Canada.

Disclaimers

All inferences, opinions, and conclusions drawn in this study are those of the authors, and do not reflect the opinions or policies of the Data Stewards. As of May 2018, DNM has been providing consulting services to the Midwives Association of BC. No other authors have competing

interests to declare. Funding sources had no involvement in the study; the authors are independent of all funders.

Contributors

DNM designed the study, conducted the statistical analyses, interpreted the results, drafted the initial manuscript, and revised subsequent drafts. NM and PAJ designed the study, reviewed the statistical analyses, interpreted the results, and reviewed and revised the manuscript. SV, MM and DM contributed to study design and clinical interpretation, and reviewed and revised the manuscript. UT contributed to interpretation, and reviewed and revised the manuscript. All authors approved the final manuscript.

Data Sharing

No additional data available.

Figure Legend

Figure 1: Eligibility flow chart Total number of pregnancies meeting inclusion/exclusion criteria by cohort.

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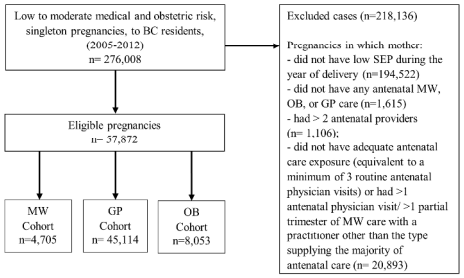

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APPENDIX A: Inclusion/exclusion variables and ICD 10-CA codes

Variables	Available in the PDR Checklist and/or as ICD 10-CA Codes
BC Health Service Delivery Area (resident)	Grouped into the following categories: • BC Resident • All other categories (excluded)
Number of births	Grouped into the following categories: • Singleton • All other categories (excluded)
Maternal diseases of the circulatory system and blood/blood forming organs	Codes beginning with: O99.1 Other disease of the blood and blood-forming organs and certain disorders involving the immune mechanism complicating pregnancy O99.4 Disease of the circulatory system complicating pregnancy O99.8 Other specified disease and conditions complicating pregnancy, childbirth and the puerperium
Pre-existing hypertension complicating pregnancy, hypertensive heart disease, hypertension secondary to renal disease	Codes beginning with: O10.1 Pre-existing hypertensive heart disease complicating pregnancy, childbirth, and the puerperium O10.2 Pre-existing hypertensive renal disease complicating pregnancy, childbirth and the puerperium O10.3 Pre-existing hypertensive heart and renal disease complicating pregnancy, childbirth and the puerperium O10.4 Pre-existing secondary hypertension complicating pregnancy, childbirth and the puerperium O10.9 Unspecified pre-existing hypertension complicating pregnancy, childbirth and the puerperium
Antihypertensive drugs, hypertensive chronic renal disease, hypertension due to other causes	Grouped into the following categories: • Yes (excluded) • No
Diabetes mellitus (insulin dependent), diabetes mellitus (non-insulin dependent)	Grouped into the following categories: • Yes (excluded) • No Codes beginning with: O24.5 Pre-existing type 1 diabetes mellitus in pregnancy O24.6 Pre-existing type 2 diabetes mellitus in pregnancy O24.7 Pre-existing diabetes mellitus of other or unspecified type in pregnancy

Liver disorders	Codes beginning with: O26.6 Liver disorders in pregnancy, childbirth and the puerperium
Tuberculosis, malaria	Codes beginning with: O98.0 Tuberculosis complicating pregnancy, childbirth and the puerperium O98.6 Protozoal diseases complicating pregnancy, childbirth and the puerperium
Number of previous pre-term deliveries	Grouped into the following categories: • ≤1 • >1 (excluded)
Previous cesarean deliveries	Grouped into the following categories: • ≤2 • >2 (excluded)
Number of spontaneous abortions	Grouped into the following categories: • ≤2 • >2 (excluded)
Pre-eclampsia, eclampsia, or either superimposed on pre-existing hypertension	Codes beginning with: O11 Pre-existing hypertensive disorder with superimposed proteinuria O14 Gestational hypertension with significant proteinuria O15 Eclampsia O16 Unspecified maternal hypertension
Hemorrhage from placenta previa	Codes beginning with: O44.1 Placenta praevia with haemorrhage
Rh immunoglobulin given or isoimmunization	Grouped into the following categories: • Yes (excluded) • No Codes beginning with: O36.0 Maternal care for rhesus isoimmunization O36.1 Maternal care of other isoimmunization
Incompetent cervix	Codes beginning with: O34.3 Maternal care for cervical incompetence
Severe hyperemesis	O21.1 Hyperemesis gravidarum with metabolic disturbance
Maternal age	Grouped into the following categories: • ≥ 14 years • < 14 years (excluded)
Delivery date/Infant birth date	Grouped into the following categories: • 1 Jan. 2005 to 31 Dec. 2012 • All other categories (excluded)
Variables	**Codes available in the MSP Payment Information File**
General practitioner routine antenatal visit	Claim specialty code "General Practice" and fee item code: • 14090 prenatal visit complete exam or

	• 14091 prenatal visit subsequent exam or • 04717 prenatal office visit complex obstetrical patient
Obstetrician routine antenatal visit	Claim specialty code "Obstetrician" and fee item code: • 14090 prenatal visit complete exam or • 14091 prenatal visit subsequent exam or • 04717 prenatal office visit complex obstetrical patient
Full or partial trimester of midwifery care	Fee item code: • 36010 midwife phase 1 (1rst trimester) total care • 36014 midwife phase 1 (1rst trimester) trans. to other 40% • 36016 midwife phase 1 (1rst trimester) trans. to other 60% • 36020 midwife phase 2 (2nd trimester) total care • 36024 midwife phase 2 (2nd trimester) trans. to other 40% • 36026 midwife phase 2 (2nd trimester) trans. to other 60% • 36030 midwife phase 3 (3rd trimester) total care • 36034 midwife phase 3 (3rd trimester) trans. to other 40% • 36036 midwife Phase 3 (3rd trimester) trans. to other 60%
MSP regular premium subsidy assistance	Subsidy code: • A (100%), B (80%), F (60%), G (40%), H (100% paid by social services)

APPENDIX B: Covariate description, data source, and ICD 10-CA codes

Variable	Description	PDR Checklist or ICD 10-CA Codes	Data Source
Maternal age	Age at date of delivery	Grouped into the following categories: • 14-19 • 20-24 • 25-29 • 30-34 • 35-39 • ≥ 40	PDR
Parity		Grouped into the following categories: • Nulliparous • Multiparous	PDR
Medical risk	Maternal disease of the respiratory or digestive system, and endocrine, nutritional, or metabolic disease	O99.5 Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium O99.6 Disease of the digestive system complicating pregnancy, childbirth and the puerperium O99.2 Endocrine, nutritional and metabolic disease complicating pregnancy, childbirth and the puerperium	PDR
Prior obstetric risk	Has had at least one of the following conditions in past pregnancy: neonatal death, stillbirth, infant with major congenital anomaly, or 1 preterm delivery	Grouped into the following categories: • Yes • No	PDR
Mental disorder or illness	Anxiety, depression, bipolar, postpartum depression, other and unknown mental disorders	Grouped into the following categories: • Yes • No	PDR

		Codes beginning with: F20 Paranoid schizophrenia F21 Schizotypal disorder F22 Delusional disorders F23 Brief psychotic disorder F24 Shared psychotic disorder F25 Schizoaffective disorder F28 Other psychotic disorder not due to a substance or known physiological condition F29 Unspecified psychosis not due to a substance or known physiological condition F30 Manic episode F31 Biopolar disorder F32 Major depressive disorder, single episode F33 Major depressive disorder, recurrent F34 Persistent mood [affective] disorders F39 Unspecified mood [affective] disorder F40 Phobic anxiety disorders F41 Anxiety disorder F42 Obsessive-compulsive disorder F43 Acute stress reaction O99.3 Mental disorders and disease of the nervous system complicating pregnancy, childbirth and the puerperium	
Receiving social assistance	Regular MSP subsidy assistance paid for by the Ministry of Employment and Income Assistance	Grouped into the following categories: • MSP subsidy assistance code H (100% subsidy) • All other categories (excluded)	MSP Payment Information File
Pre-pregnancy BMI	Ratio of a women's pre-pregnancy weight (kg) to height (m)	Grouped into the following categories: • Underweight (<18.5) • Normal (18.5-24.9) • Overweight (25-29.9) • Obese (≥ 30) • Unknown	PDR
Smoking status		Grouped into the following categories: • Never • Former • Current • Unknown	PDR

Substance use	Heroin/opioids, cocaine, methadone, solvents, prescription, marijuana, other, unknown drugs	Grouped into the following categories: • Yes • No or blank Codes beginning with: F11 Opioid dependence, abuse, use F12 Cannabis dependence, abuse, use F13 Sedative, hypnotic or anxiolytic dependence, abuse, use F14 Cocaine dependence, abuse, use F15 Other stimulant dependence, abuse, use F16 Hallucinogen dependence, abuse, use F18 Inhalant dependence, abuse, use F19 Other psychoactive substance dependence, abuse, use	PDR
Alcohol use	Alcohol during pregnancy identified as a risk by care provider	Grouped into the following categories: • Yes • No or blank Codes beginning with: F10 Alcohol dependence, abuse, use with alcohol-induced disorder	PDR
Antepartum morbidity	Hypertension (≥ 140/90) during pregnancy, pregnancy induced hypertension, gestational diabetes insulin dependent, non-insulin dependent, IUGR identified as a risk during the antenatal period, antepartum hemorrhage ≥ 20 weeks	Grouped into the following categories: • Yes • No Codes beginning with: O13 Gestational hypertension w/o significant proteinuria O24.8 Diabetes mellitus arising in pregnancy (gestational) O99.0 Anemia complicating pregnancy, childbirth and the puerperium O99.0 Maternal care for restricted fetal growth O98.4 Viral hepatitis complicating pregnancy, childbirth and the puerperium O98.5 Other viral diseases complicating pregnancy, childbirth and the puerperium O98.8 Other maternal infectious and parasitic disease complicating pregnancy, childbirth and the puerperium O98.9 Unspecified maternal infectious or parasitic disease complicating pregnancy, childbirth and the puerperium O44.0 Placenta previa specified as without	PDR

		haemorrhage O40 Polyhydramnios O41 Oligohydramnios O98.1 Syphilis complicating pregnancy, childbirth and the puerperium O98.2 Gonorrhoea complicating pregnancy, childbirth and the puerperium O98.3 Other infections with a predominantly sexual mode of transmission complicating pregnancy, childbirth and the puerperium O98.7 Human immunodeficiency disease complicating pregnancy, childbirth and the puerperium O45 Premature separation of placenta	
Delivery Year		Grouped into the following categories: • 2005 • 2006 • 2007 • 2008 • 2009 • 2010 • 2011 • 2012	PDR
Neighbour-hood SEP	Assigned on the basis of residence, reflects the average single-person income in a geographical area populated by approximately 400-700 people	Grouped into the following categories: • High • Low/Medium	Population Data BC, Consolid-ation File
Urban/rural residence	Population estimates (2009) of LHAs	Grouped into the following categories: • Urban • Rural • Unknown	BC Stats
LHA socioecono-mic index	LHAs in BC ranked according to area-level socioeconomic status, based on six indicators: human economic hardship, crime concerns, health problems,	Grouped into the following categories: • High • Medium • Low • Unknown	BC Stats and a number of social ministries[a]

	education concerns, children at risk, and youth at risk		
LHA income inequality	LHAs in BC ranked according to area-level income inequality	Grouped into the following categories: • High • Medium • Low • Unknown	BC Stats
Northern residence	Residing in the Northern Health Authority at delivery	Grouped into the following categories: • Yes • No	PDR
Gestational age at birth, in completed weeks	Calculated by algorithm incorporating last menstrual period, first ultrasound, infant exam, and maternal chart[b]	Used for coding small-for-gestational-age and preterm birth	PDR
Small-for-gestational-age birth	Based on admission weight in grams and infant's gestational age at birth in completed weeks (20 to 44 weeks)	Grouped according to Kierans' sex-specific birth weight standards[c]	PDR
Preterm birth	Infant's gestational age at birth in completed weeks	Grouped into the following categories: • 20 to 36 weeks • Other (excluded)	PDR

[a] BC Stats. Socio-economic indices: LHA indices reports. Human economic hardship: income inequality measure. 2013 [cited 2014 Nov 4]. From: http://www.bcstats.gov.bc.ca/StatisticsBySubject/SocialStatistics/SocioEconomicProfilesIndices/SocioEconomicIndices/LHAReports.aspx.

[b] Algorithm for the estimation of gestational age. Canadian Perinatal Surveillance System. Ottawa: Public Health Agency of Canada; 2010.

[c] Kierans W, Kramer M, Wilkins R, et al. Charting birth outcome in British Columbia: determinants of optimal health and ultimate risk--an expansion and update. Vancouver, BC: British Columbia Vital Statistics Agency; 2008 [cited 2017 Feb 16]. From: http://www.perinatalservicesbc.ca/Documents/Resources/HealthPromotion/BirthCharts/ChartingBirthOutcomeReport.pdf.

Appendix C: Sensitivity analyses

Table 1: Adjusted odds ratios with and without control for antepartum morbidity

Antenatal Model	Without Control for Antepartum Morbidity OR (95% CI)	With Control for Antepartum Morbidity OR (95% CI)
Small-for-Gestational-Age Birth (< 10th percentile)[a]		
MW vs. GP	0·71 (0·62-0·82)	0·77 (0·67-0·89)
MW vs. OB	0·59 (0·50-0·69)	0·68 (0·59-0·80)
GP vs. OB	0·83 (0·76-0·91)	0·88 (0·80-0·96)
Preterm Birth (< 37 weeks gestation)[b]		
MW vs. GP	0·74 (0·63-0·86)	0·80 (0·69-0·93)
MW vs. OB	0·53 (0·45-0·62)	0·61 (0·51-0·71)
GP vs. OB	0·72 (0·65-0·79)	0·75 (0·69-0·83)
Low Birth Weight (<2500 g.)[c]		
MW vs. GP	0·66 (0·53-0·82)	0·80 (0·64-0·99)
MW vs. OB	0·43 (0·34-0·54)	0·58 (0·46-0·74)
GP vs. OB	0·65 (0·58-0·74)	0·73 (0·64-0·83)

All models adjusted for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status and substance use.
[a]Model also adjusted for mental illness, and LHA socioeconomic rank.
[b]Model also adjusted for medical risk, prior obstetric risk, delivery year, receipt of social assistance, alcohol use, mental illness, neighbourhood SEP, LHA socioeconomic rank, LHA income inequality, and northern residence.
[c]Model also adjusted for prior obstetric risk.

Table 2: Adjusted odds ratios for full study population excluding pregnancies in which mothers had prior medical or obstetric risk (n=55,041)

Antenatal Model	OR (95% CI)
Small-for-Gestational-Age Birth (< 10th percentile)[a]	
MW vs. GP	0·71 (0·61-0·82)
MW vs. OB	0·59 (0·51-0·70)
GP vs. OB	0·84 (0·77-0·93)
Preterm Birth (< 37 weeks gestation)[b]	
MW vs. GP	0·72 (0·61-0·84)
MW vs. OB	0·52 (0·43-0·61)
GP vs. OB	0·72 (0·65-0·80)
Low Birth Weight (<2500 g.)	
MW vs. GP	0·66 (0·53-0·82)
MW vs. OB	0·44 (0·35-0·56)
GP vs. OB	0·67 (0·59-0·76)
All models adjusted for maternal age, parity, pre-pregnancy BMI, infant sex, smoking status and substance use. [a]Model also adjusted for mental illness, and LHA socioeconomic rank. [b]Model also adjusted for delivery year, receipt of social assistance, alcohol use, mental illness, neighbourhood SEP, LHA socioeconomic rank, LHA income inequality, and northern residence.	

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **On the title page and Methods section of the abstract**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Methods and Results sections of the abstract**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Introduction (pg. 6)**
Objectives	3	State specific objectives, including any prespecified hypotheses **Last sentence of the introduction (pg.6)**
Methods		
Study design	4	Present key elements of study design early in the paper **Methods (pgs. 6-7)**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Methods (pgs. 6-9)**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **Methods (pgs. 10) and Appendix A**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed **N/A**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Methods (pgs. 10, 11) and Appendix B**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Methods (pgs. 12-13) and Appendix B**
Bias	9	Describe any efforts to address potential sources of bias **Methods (pg. 14), Results (pg. 20), Discussion (pg. 23), and Appendix C**
Study size	10	Explain how the study size was arrived at **Methods (pg. 11-12)**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Methods (pg. 12-13) and Appendix B**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **Methods (pgs. 12-14)**
		(*b*) Describe any methods used to examine subgroups and interactions **N/A**
		(*c*) Explain how missing data were addressed **Methods (pg. 16)**
		(*d*) If applicable, explain how loss to follow-up was addressed **N/A**
		(*e*) Describe any sensitivity analyses **Methods (pg. 14)**

Results		
Participants	13*	*(a)* Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Figure 1: Eligibility Flow Chart**
		(b) Give reasons for non-participation at each stage **Figure 1: Eligibility Flow Chart**
		(c) Consider use of a flow diagram **Figure 1: Eligibility Flow Chart**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Table 2 (pgs. 16-17) and Results (pgs. 18)**
		(b) Indicate number of participants with missing data for each variable of interest **Table 2 (pgs. 16-17)**
		(c) Summarise follow-up time (eg, average and total amount) **N/A**
Outcome data	15*	Report numbers of outcome events or summary measures over time **Table 3 and Results (pg. 18)**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **Results (pgs. 18-19), and Table 3 (pg. 19)**
		(*b*) Report category boundaries when continuous variables were categorized **Table 2 (pgs. 16-17)**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **N/A**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **Results (pg. 20-21), Appendix C**
Discussion		
Key results	18	Summarise key results with reference to study objectives **First line of Discussion (pg. 21)**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Discussion (pgs. 21-22), Appendix C**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Discussion (pgs. 24-26)**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Discussion (pg. 21)**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Acknowledgments (pg. 27), Disclaimers (pg. 27)**

*Give information separately for exposed and unexposed groups.