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Relative effectiveness and cost-effectiveness of the midwifery-led care in Nova Scotia, Canada: A retrospective, cohort study

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ABSTRACT

Objectives: To compare neonatal and maternal outcomes, and the relative risk of interventions between mothers attended to by midwives, general practitioners, and obstetricians, and to assess the cost-effectiveness of the employee-model of midwifery-led care in Nova Scotia, Canada, when compared with general practitioners.
Design, setting, and participants: The study was a retrospective cohort study involving routinely collected clinical and administrative data from all low-risk births from January 1st, 2013 to December 31st, 2017. There were 24,662 observations.
Measurements: Descriptive statistics were used to summarise the mother's socio-demographic characteristics. We used a nearest-neighbour matching estimator in assessing differences in outcomes, and generalized linear models in the estimation of the risks of interventions, adjusting for potential confounders. An analytic decision tree served as the vehicle for the cost-effectiveness analysis, assessed using the net monetary benefit approach. All health care resources utilized were measured and valued. Neonatal intensive care admissions avoided was the measure of outcome. We performed probabilistic sensitivity and subgroup analyses.
Findings: Mothers attended to by midwives spent less time at the hospital during birth admissions, were less likely to have interventions, instrumental births, and more likely to have exclusive breastfeeding at discharge from birth admission. There were no differences in Apgar scores and neonatal intensive care unit admissions. The employee-model of midwifery-led care was found to be cost-effective.
Key conclusions: The midwifery program is both effective and cost-effective for low-risk pregnancies
Implications for practice: Increasing the number of midwives will increase access and represents value for money.

Introduction

Women's access to the best possible health care during pregnancy and childbirth is critical to achieving the sustainable development goal of reducing global maternal and neonatal mortality rates. Increasingly, the role of midwives in women's access to health care is gaining significance, both in developing and developed countries, driven in part, by the increasing evidence in favour of midwifery-led care (MLC) (Donnellan-Fernandez et al., 2018; Homer et al., 2017; Rayment-Jones et al., 2015; Sandall et al., 2016; Walters et al., 2015)—the World Health Organisation recommended MLC in its 2016 guidelines on intrapartum care (World Health Organization, 2016, p. 89).

There are three types of MLC models in Canada, namely, independent contractors: paid per course of care (British Columbia, Alberta, and Ontario); salaried-employees (Saskatchewan, Manitoba, Quebec, New Brunswick, Northwest Territories, Nova Scotia, and Nunavut); and unregulated private practice: practitioners charge private fees for their service. In 2009, the midwifery program in Nova Scotia (NS) became government funded and regulated. So in early 2018, the Izaak Walton Killam (IWK) Health Centre and the NS Health Authority (NSHA) were evaluating the development and sustainability of the midwifery service as part of strategic planning

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for their Maternal and Newborn Program. The strategic review and planning process requires assessing whether increasing the number of midwives in the province provides value for money, information that was not available for the province.

The literature on the effectiveness of MLC models includes mixed results, with some results showing reduced interventions and comparatively better neonatal and maternal outcomes (Homer et al., 2017; Sandall et al., 2016), while others report increased interventions associated with MLC (Voon et al., 2017). The inconsistencies in the literature warrant further research. In a 2016 Cochrane review, Sandall et al. (2016) investigated whether interventions, pharmaceutical pain relief use, method of birth, and breastfeeding initiation differ between MLC models and 'other models of care.' However, the 'other models of care' was a composite of obstetrician-provided care, family doctor-provided care, and shared models of care which involved different health professionals. The composite nature of the comparator group means that it is not evident if the results will hold in a disaggregated analysis.

The literature on the cost-effectiveness of MLC models consists of studies from countries with health care systems characterized by different institutional arrangements and funding models, hindering meaningful inter-country comparison and the generalization of results (Donnellan-Fernandez et al., 2018). In the international literature, Ryan et al. (2013), United Kingdom, and Toohill et al. (2012), Australia, reported finding cost-effectiveness of MLC models. At the same time, Ryan et al. highlighted the limitedness of existing evidence and the need for further research. In the Canadian context, Walters et al. (2015) assessed the cost-effectiveness of the independent-contractor model of the MLC in Ontario, Canada; however, whether the employee-model of MLC in NS, Canada, is cost-effective, remains unknown.

This study assessed the relative effectiveness and cost-effectiveness of the MLC model in NS. The first part of the study compares neonatal and maternal outcomes between the service providers, made up of midwives (MW), family physicians (FP), and obstetricians and gynaecologists (OB/GYN). The second part assessed the cost-effectiveness of maternity-related services provided by MW compared to FP. The research questions were: Are there statistically significant differences in maternal and neonatal outcomes between the service providers?; And, from the perspective of the Department of Health and Wellness in NS, compared to maternity-related services provided by FP, is the employee-model of the MLC model cost-effective?

To the best of our knowledge, this study was the first to assess the relative effectiveness and cost-effectiveness of the employee-model of the MLC in Canada. Our study demonstrates the potential for leveraging data from administrative and clinical databases for cost-effectiveness studies. At the minimum, this study provides an objective and robust economic evaluation of the midwifery program and will serve as an essential input into discussions and decisions on the potential contributions of midwives in women's access to health care in other countries.

Methods

Relative effectiveness of the midwifery program

Study design

The study was a retrospective cohort study involving routinely collected clinical and administrative data from all low-risk births in NS from January 1st, 2013 to December 31st, 2017.

Setting

The data came from the NS Atlee Perinatal Database (NSAPD), administered by the Reproductive Care Program (RCP): it contains demographic variables, procedures, interventions, maternal and newborn diagnoses, and morbidity and mortality information for all pregnancies and births occurring in NS since 1988. The data includes observations from all hospitals in the province that provide maternity care. The study received approvals from the NSHA Research Ethics Board (REB), the IWK REB, and the RCP Data Access Committee in 2018. Submitting a detailed study protocol with clearly defined research questions before accessing the data served to prevent the possibility of data dredging (Berger et al., 2017; Cox et al., 2009).

Participants

The exclusion criteria were fetuses greater than one (Walters et al., 2015), preterm birth (<37 weeks of gestation) (Homer et al., 2014), presence of blood dyscrasias affecting pregnancy, endocrine disease affecting pregnancy, birth weight less than 2500 g, elective caesarean section (Homer et al., 2014), newborn diagnosed with major congenital abnormality, induction - post-due date at 41 weeks or later (RCP), maternal pre-existing hypertension or diabetes, gestational hypertension or diabetes (Walters et al., 2015), caesarean section in previous two years or less (RCP), placenta previa/accreta/increta/percreta, and maternal complications, for example: heart defect, connective tissue disorders, blood dyscrasias, and endocrine disease (RCP). Participants would qualify for inclusion if the newborn were in cephalic presentation. Administrators of the NSAPD independently applied the inclusion and exclusion criteria to select the estimation sample.

Main exposure

The exposure was the mothers' attending service provider, made up of MW, FP, and OB/GYN.

Outcome variables—neonatal and maternal outcomes

The neonatal outcomes were admissions to the neonatal intensive care unit (NICU), exclusive breastfeeding at discharge from birth admission; Apgar score less than seven at 5 minutes, and whether the newborn was alive at discharge from birth and neonatal admissions. The maternal outcomes were postpartum haemorrhage, postpartum length of stay, length of stay during birth admission, and the combined length of stay during birth plus any neonatal admissions.

Outcome variables—interventions

The interventions were labour augmentation or induction, comprising any of amniotomy, oxytocin, and prostaglandin use; pharmaceutical pain relief use—a binary variable coded one if the expectant mother received any of nitrous oxide, epidural anaesthesia, spinal anaesthesia, morphine, and fentanyl, and zero otherwise; spontaneous vaginal birth, assisted vaginal birth (forceps and vacuum), and non-elective caesarean birth.

Confounding variables

The confounding variables were maternal fever higher than 38 °C, supervised pregnancy with insufficient antenatal care, marital status, pre-pregnancy number of cigarettes smoked per day, the highest level of education completed, body mass index (BMI), location, method of birth, and the quintile of neighborhood annual income per person equivalent.

Statistical analysis

This study followed the intention-to-treat (ITT) approach. Sample socio-demographic characteristics were summarized using frequencies and percentages. A non-parametric matching estimator, the nearest-neighbour matching (NNM) estimator, was used to estimate differences in outcomes (Abadie and Imbens, 2011). It involved comparing outcomes of participants that are as similar as possible and differ only in the mothers' type of service provider. The NNM uses the distance between covariate patterns to define similarity, measured using the Mahalanobis distance metric (Abadie and Imbens, 2011). Standardized differences and variance ratios of the covariates in the groups were used as diagnostic checks for the quality of the matching (Austin, 2011). The NNM estimator reduces potential selection biases (Abadie and Imbens, 2011). The NNM was implemented using the *teffects nnmatch* command in Stata, version 15.1 (Cattaneo et al., 2013). We estimated adjusted relative risks (RR) of interventions using generalised linear models with a binomial family and a log link function. Covariates were deemed statistically significant if p-value < 0.05. All statistical analyses were performed using Stata (version 15.1) software (StataCorp. 2017). We conducted subgroup analyses based on location and parity.

Economic evaluation

As an overview, the economic evaluation was a cost-effectiveness analysis, which involves comparing two or more alternative courses of action in terms of both costs and outcomes to aid policy decisions (Drummond et al., 2015, p. 4). There is a preference for an intervention that is less costly and offers more benefits compared to an expensive and ineffective comparator. If the intervention offers more benefits but is more costly, there is a trade-off, and a willingness-to-pay (WTP) threshold, λ, serves as a benchmark for assessing cost-effectiveness (Glick et al., 2014, p. 196). We used an analytic decision model (Fig. 1, drawn in TreeAge Pro, 2018) for the cost-effectiveness analysis, using the same NSAPD data to generate probabilities for the model, supplemented with cost data.

Target population and setting

The target population was low-risk pregnancies in NS.

Comparators

Mothers attended to by MW constituted the intervention arm, and FP, the comparator. Although all service providers provide in-hospital obstetrical care, we reasoned that OB/GYN in some of the Units typically offer specialist service and therefore may not be appropriate to compare them to MW and FP in the economic evaluation.

Time horizon and discounting

The analysis covers antepartum, intrapartum, and up to six weeks postpartum, which is less than a year, so no discounting of costs and outcomes was necessary (Glick et al., 2014, p. 57).

Health outcome

We followed Walters et al. (2015) in choosing the health outcome used in the economic evaluation: NICU admission avoided, which takes a value of 1 if there was no NICU admission and zero otherwise (zero entered in the model as 0.01). See the terminal node of Fig. 1.

Analytic decision model, resources and costs

Fig. 1 is a decision tree that served as the vehicle for the cost-effectiveness analysis. It illustrates the possible combinations of interventions, methods of birth, and outcomes associated with each service provider, drawn in consultation with experts from the RCP. For each arm of the tree, the health resources used were identified, measured, and valued. The approach to costing the services provided by FP follows Walters et al. (2015). Physician fees for antepartum visits, interventions, birth, and postpartum care came from the 2014 NS Medical Services Insurance Physician Manual—the current version as at July 2018. All hospital costs came from the Canadian Institute of Health Information (CIHI) case-mix group (CMG) patient cost estimator for NS. We measured costs in 2017 Canadian dollars (C$). The OB/GYN fee for caesarean section birth for a MW client goes to the MW arm, consistent with the ITT principle. The OB/GYN fee for caesarean section birth for an MW client goes to the MW arm. We assumed the same inpatient costs associated with admission and birth for all service providers (Table 5).

After birth, the attending service provider examines the newborn, and the associated fee for the examination counted. In the case of no admission to NICU, the applicable additional fees were the fees for the initial examination and the postpartum care visits. NICU related expenses consist of two parts; physician fees that vary by the number of days on admission and the average inpatient case cost. The second part of the NICU costs comes from the inpatients, estimated as the average of CIHI codes CMG 589–599, following Walters et al. (Table 5). The average yearly salary with benefits for a midwife in NS was C$ 91,624, with an average caseload of 32 women per year; resulting in C$ 2,863 per case, without intervention and hospital-related costs.

Probabilities

All probabilities used to parameterize the analytic decision model (Fig. 1) were estimated from confounder-adjusted logistic regressions using data from the NSAPD (Briggs et al., 2013, p. 97). See Table 6.

Assessing cost-effectiveness

Cost-effectiveness was assessed using the net monetary benefit (*NMB*), and the incremental cost-effectiveness ratio (*ICER*) for robustness checks. The *NMB* was computed as:

$$NMB = \lambda * \Delta E - \Delta C$$

where λ denotes the WTP threshold; ΔE denotes the difference in the expected NICU admissions avoided between the two groups, and ΔC denotes the difference in the expected costs: we subtracted FP costs (and benefits) from MW costs (and benefits). Cost-effectiveness requires that the estimated *NMB* be greater than zero and the associated 95% confidence interval (95% CI), from sensitivity analysis, should exclude zero (Glick et al., 2014, p. 196). Similarly, the ICER was computed as:

$$ICER = \frac{\Delta C}{\Delta E}$$

Cost-effectiveness requires that the estimated $ICER < \lambda$ (Glick et al., 2014, p. 196).

Sensitivity and subgroup analyses for cost-effectiveness

We conducted multi-way probabilistic sensitivity analysis (PSA). In the PSA, key parameters were allowed to vary simultaneously, and the results evaluated (Drummond et al., 2015, p. 60). The uncertainty surrounding costs was modelled using a gamma distribution, and probabilities, a beta distribution (Briggs et al., 2013, p. 86). A Monte Carlo simulation was used to generate 1000 simulated trials, and the results used to calculate the 95% CI around the *NMB* and the *ICER*, using the percentile method (Briggs et al., 2013,

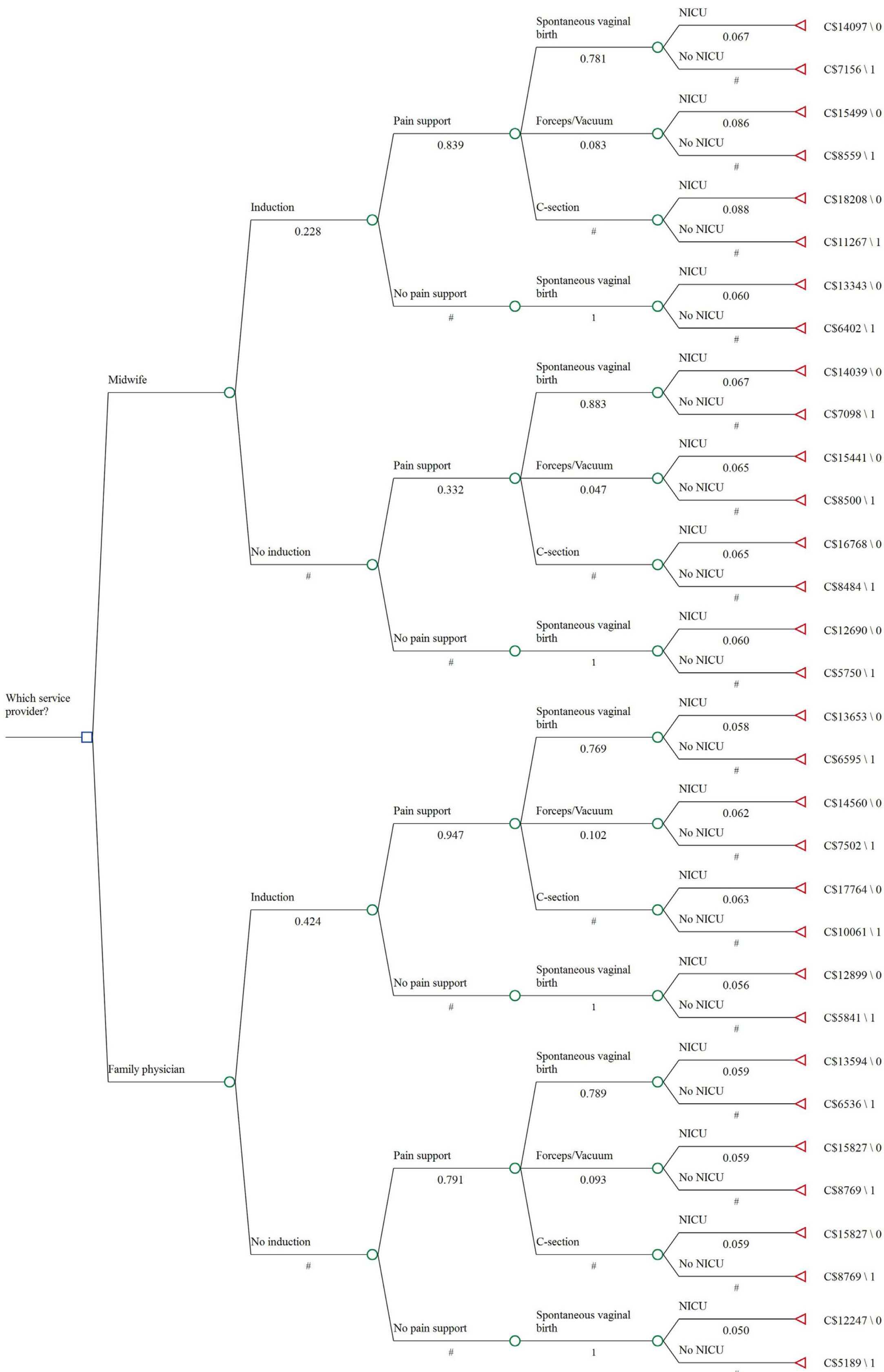

Fig. 1. Decision tree showing the probabilities, costs (C$), and outcomes associated with each pathway.

Table 1
Study participants' socio-demographic characteristics.

Variable	Midwife ($N=753$) n (%)	General/family practitioner ($N=12,434$) n (%)	Obstetrician/gynaecologist ($N=11,475$) n (%)
Insufficient ante-natal care			
Yes	–	102 (0.82)	44 (0.38)
No	753 (100)	12,332 (99.18)	11,431 (99.62)
Marital status			
Single	128 (17.00)	4332 (34.84)	3545 (30.89)
Married	485 (64.41)	5726 (46.05)	5516 (48.07)
Separated	–	39 (0.31)	46 (0.40)
Common-law	138 (18.33)	2325 (18.70)	2356 (20.53)
Pre-pregnancy cigarettes per day			
None	695 (92.30)	9901 (79.63)	8992 (78.36)
Half pack	28 (3.72)	771 (6.20)	792 (6.90)
Less than but one but more than half	13 (1.73)	904 (7.27)	855 (7.45)
One pack	–	140 (1.13)	101 (0.88)
Unknown	–	718 (5.77)	735 (6.41)
Highest level of education completed			
Less than secondary	15 (1.99)	527 (4.24)	609 (5.31)
Secondary	53 (7.04)	1276 (10.26)	1420 (12.37)
Technical/some post-secondary	99 (13.15)	1364 (10.97)	1391 (12.12)
Post-secondary	181 (24.04)	1716 (13.80)	1944 (16.94)
Graduate level	78 (10.36)	335 (2.69)	286 (2.49)
Post-graduate level	10 (1.33)	73 (0.59)	35 (0.31)
Professional degree	13 (1.73)	103 (0.83)	89 (0.78)
Unknown	304 (40.37)	7040 (56.62)	5701 (49.68)
Quintile of neighbourhood annual income per person equivalent			
Quintile 1	107 (14.21)	2391 (19.23)	1916 (16.70)
Quintile 2	152 (20.19)	2494 (20.06)	2381 (20.75)
Quintile 3	198 (26.29)	2616 (21.04)	2546 (22.19)
Quintile 4	149 (19.79)	2456 (19.75)	2831 (24.67)
Quintile 5	128 (17.00)	1957 (15.74)	1550 (13.51)
Unknown	19 (2.52)	520 (4.18)	251 (2.19)
Race/ethnicity: caucasian			
Yes	573 (77.64)	5600 (45.74)	6053 (53.11)
No	165 (22.36)	6642 (54.26)	5344 (46.89)
Maternal pre-pregnancy weight status			
Underweight (BMI $<$ 18.5)	21 (2.79)	513 (4.13)	441 (3.84)
Normal (18.5 $\leq$ BMI $<$ 25	440 (58.43)	5521 (44.40)	4668 (40.68)
Overweight (25 $\leq$ BMI $<$ 30)	139 (18.46)	2424 (19.49)	2350 (20.48)
Obese (BMI $\geq$ 30)	153 (20.32)	3976 (31.98)	4016 (35.00)
Location			
Rural	192 (25.50)	2475 (19.91)	4280 (37.30)
Urban	561 (74.50)	9959 (80.09)	7195 (62.70)
Parity			
Nulliparous	276 (36.65)	5635 (45.32)	4464 (38.90)
Multiparous	477 (63.35)	6799 (54.68)	7011 (61.10)
Maternal fever > 38 °C			
Yes	21 (2.79)	626 (5.03)	403 (3.51)
No	732 (97.21)	11,808 (94.97)	11,072 (96.49)
Number of previous C-sections			
0	681 (91.53)	11,606 (94.22)	9373 (82.39)
1	61 (8.20)	649 (5.27)	1581 (13.90)
2	–	53 (0.43)	347 (3.05)

BMI = body mass index.

p. 158). Cost-effectiveness acceptability curve (CEAC), which shows how the probability that an intervention is cost-effective changes at various levels of λ, and cost-effectiveness planes were used to summarize the results from the simulations. Also, the analysis was repeated, allowing the cost per case for MW to increase by 10% and 15%. Further, we conducted subgroup analyses based on location and parity, using probabilities generated from data from these subgroups. Also, we conducted additional sensitivity analysis for a scenario that excludes the average direct cost per visit in the FP arm.

Results

Population characteristics

The sample consisted of 24,662 low-risk pregnancies, made up of 753 (3.1%) mothers attended to by MW, 12,434 (50.4%) for FP, and 11,475 (46.5%) for OB/GYN. Table 1 reports the study participants' socio-demographic characteristics.

Effectiveness of the midwifery program

There was a statistically significant (p-value $<$ 0.00) difference in the proportion of women who breastfed exclusively between MW (90%) and FP (67%), and between MW and OB/GYN (67%). There were more cases of postpartum haemorrhage in FP than in OB/GYN (p-value $<$ 0.00) (Table 2). Overall, mothers attended to by FP and OB/GYN spent more hours at the hospital during birth and neonatal admissions than those attended to by MW (Table 3); OB/GYN clients spent more hours than those of FB. These results held in subgroup analyses (See Tables S1 and S2).

Table 4 reports the RR of interventions. Compared to FP, MW clients were more likely to experience a spontaneous vaginal birth, less likely to have an induction, less likely to have pain support,

Table 2
Differences in discrete maternal and neonatal outcomes.

Variable	Unmatched sample[a]			Differences in proportions, matched sample using the NNM estimator[c]		
	MW ($N = 753$) n (%)	FP ($N = 12,434$) n (%)	OB/GYN ($N = 11,475$) n (%)	MW vs FP($N = 12,980$) P-value	MW vs OB/GYN ($N = 12,135$) P-value	FP vs OB/GYN ($N = 23,639$) P-value
Admission to NICU						
No NICU admission	717(95.22)	11,694 (94.05)	10,871 (94.74)	0.56	0.07	**0.01**
≥ 1 NICU admission	36 (4.78)	740 (5.95)	604 (5.26)			
Postpartum haemorrhage						
Yes	53 (7.04)	1079 (8.68)	690 (6.01)	0.12	0.25	**< 0.00**
No	700 (92.96)	11,347 (91.26)	10,785 (93.99)			
Breastfeeding at discharge from birth admission						
Breastfed - exclusively	676 (89.77)	8387 (67.45)	7631 (66.50)	**< 0.00**	**< 0.00**	**< 0.00**
No exclusive breastfeeding[b]	77 (10.23)	4047 (32.55)	3844 (33.50)			
Apgar scores less than seven at 5 min.						
< = 6	15 (1.99)	214 (1.72)	191 (1.66)	0.41	0.35	0.54
> 6	738 (98.01)	12,220 (98.28)	11,284 (98.34)			
Neonatal outcome						
Baby lived	751 (99.73)	12,423 (99.91)	11,458 (99.85)	0.23	0.37	0.09

NICU = neonatal intensive care unit; MW = midwife; FP = family/general practitioner; OB/GYN = obstetrician/gynaecologist.
[a] A two-sample test of equality of proportions in the unmatched sample did not yield different results.
[b] Made up of breastfeeding with supplementation and no breastfeeding.
[c] NNM = nearest-neighbour matching estimator.

and less likely to have a non-elective caesarean section. Compared to MW, OB/GYN clients were less likely to experience a spontaneous vaginal birth, more likely to have an induction, more likely to have pain support, and more likely to have a non-elective caesarean section. Compared to FP, OB/GYN clients were less likely to experience a spontaneous vaginal birth, more likely to have an induction, more likely to have pain support, and more likely to have a non-elective caesarean section. The results from the subgroup analyses mirror the results presented here. See Table S3.

Cost-effectiveness results

Table 7 shows the main results, together with the results from the PSA. The expected cost per birth associated with MW was C$ 8,308, and C$ 7,131 for FP. The expected NICU admissions avoided was 0.94 in MW, and 0.89 in FP; with the implication that MW offers more health benefits, but at a relatively higher cost. Using a WTP threshold of C$ 50,000, the *NMB* was C$ 963 (95% CI: −1,152 to 2,844), and the *ICER* was C$ 27,502 (95% CI: −4,906 to 94,665) per NICU case avoided. The probability that MW is cost-effective was 0.83.

Sensitivity and subgroup analysis

Fig. 2 shows the joint distribution of the differences in expected costs and outcomes from the 1000 simulations. Fig. 3 shows the cost-effectiveness acceptability curve, and Fig. 4 shows how the *NMB* changes with varying levels of λ. Keeping everything else the same, if the cost per case for MW increases by 10% to C$ 3,150, the expected cost per birth increases to C$ 8,602. The associated *ICER* was C$ 34,392 per NICU case avoided, and the probability of cost-effectiveness decreased to 0.78. A 15% increase in the cost per case did not change the conclusions (Table S4 and Figs. 5, S1, and S2). Similarly, the results did not change in the urban and rural subgroups, and based on parity (see Tables S5, S6, and Figs. 6, S3, and S4). The *ICER* associated with no average direct costs per visit in the FP arm was C$ 48,883. See Table S7.

Discussion and conclusions

The current study examined the relative effectiveness and cost-effectiveness of the MLC in NS, Canada. There were similarities and differences between the reported risks of interventions in the current study and the results of the review by Sandall et al. (2016). Both studies found that MW clients were more likely to have a spontaneous vaginal birth, and less likely to have pain support (see Table 4). In this study, MW clients were less likely to have an induction and non-elective caesarean section, and no difference between the groups for instrumental birth in the full sample; however, in rural areas, MW clients were less likely to have instrumental birth than FP (Table S3). Sandell et al., on the other hand, reported no difference in the relative risks for induction, and non-elective caesarean section. Our findings on interventions differ from Voon et al. (2017). The relatively large sample size with data from all health institutions providing maternity service in NS makes the sample representative of the population. A primary potential source of bias was whether mothers self-select into service provider groups. However, the matching estimator used in estimating differences in outcomes, by matching on confounding variables, reduces any potential bias.

The results from the economic evaluation showed that the MLC in NS is cost-effective, consistent with the literature (Donnellan-Fernandez et al., 2018; Ryan et al., 2013; Toohill et al., 2012; Walters et al., 2015). The main drivers of the cost-effectiveness include reduced birth interventions associated with MW. Further, we used a caseload of 32 women per MW per year; however, according to Donnellan-Fernandez et al. (2018), 40 represents optimal caseload,

Table 3
Differences in maternal outcomes, unmatched and matched sample.

Outcome	FP vs MW ($N = 12,980$) Differences (95% CI)	OB/GYN vs MW ($N = 12,135$) Differences (95% CI)	OB/GYN vs FP ($N = 23,639$) Differences (95% CI)
Unmatched (unadjusted) sample[a]			
Postpartum length of stay (hours)	20.88*** (18.62–23.13)	24.46*** (22.20–26.72)	3.59*** (2.81–4.36)
Length of stay during birth admission (hours)	12.51*** (5.38–19.63)	17.93*** (10.78–25.07)	5.42*** (3.38–7.46)
Combined length of stay during birth plus any neonatal admissions (hours)	12.46*** (4.99–19.93)	17.92*** (10.43–25.41)	5.46*** (3.28–7.65)
Matched sample[b]			
Postpartum length of stay (hours)	16.10*** (13.45–18.75)	19.02*** (16.00–22.04)	3.64*** (2.42–4.87)
Length of stay during birth admission (hours)	16.92*** (13.32–20.52)	21.38*** (17.42–25.35)	8.10*** (3.40–12.21)
Combined length of stay during birth plus any neonatal admissions (hours)	16.03*** (11.60–20.45)	20.97*** (16.54–25.39)	7.95*** (3.72–12.19)

[a] Unadjusted differences from the unmatched sample estimated using a two-sample *t*-test with unequal variances. FP = Family physician; MW = midwife; OB/GYN = obstetrician/gynaecologist.
[b] Differences in outcomes estimated using the nearest-neighbour matching estimator, with a matching outcome model, and a Mahalanobis distance metric. The matching variables include maternal fever more than 38°Celsius, supervised pregnancy with insufficient antenatal care, marital status, pre-pregnancy number of cigarettes smoked per day, the highest level of education completed, BMI, rural or urban, quintile of neighbourhood annual income per person equivalent, and method of birth. The diagnostic results showed that the standardized differences in covariates between the groups were close to zero, and the variance ratios were all close to one, with the implication that the characteristics of women in the matched sample were similar.
*** P-value < 0.01.

Table 4
Relative risk of interventions.

Intervention	MW vs FP ($N = 12,980$) Relative risk (95% CI)	OB/GYN vs MW ($N = 12,135$) Relative risk (95% CI)	OB/GYN vs FP ($N = 23,639$) Relative risk (95% CI)
Induction and or augmentation	0.52** (0.31–0.86)	1.99** (1.29–3.08)	1.02 (0.85–1.22)
Pain support	0.49** (0.32–0.73)	2.16*** (1.44–3.23)	1.04** (1.01–1.07)
Spontaneous vaginal birth	1.11** (1.04–1.18)	0.75*** (0.69–0.81)	0.83*** (0.78–0.88)
Forceps and or vacuum	0.53 (0.27–1.02)	1.90** (1.09–3.30)	0.95 (0.73–1.22)
Non-elective caesarean section birth	0.57** (0.35–0.91)	3.89*** (2.34–6.45)	2.20***(1.78–2.75)
NICU avoided	1.13 (0.87–1.48)	0.95(0.69–1.32)	1.06 (0. 68–1.67)

Relative risks estimated using generalized linear models, controlling for maternal fever more than 38 °C, supervised pregnancy with insufficient antenatal care, marital status, pre-pregnancy number of cigarettes smoked per day, the highest level of education completed, BMI, rural or urban, and quintile of neighbourhood annual income per person equivalent; FP = family physician; MW = midwife; OB/GYN = obstetrician/gynaecologist.
*** P-value < 0.01.
** P-value < 0.05.

Table 5
Common costs and service provider specific costs used in the economic evaluation.

Cost item	Mean (C$)	SE(C$)	Codes
Standard costs (common to both service providers)			
Induction of labour by artificial rupture of membranes (Consultation and procedure)	58.29	29.00	OBST 85.01
Pain support: Anaesthesia: continuous conduction anaesthesia for the relief of pain in labour	411.76	1.00†	VEDT 16.91R
Pain support: Anaesthetic Standby	210.64	1.00†	VIST 03.04
Physician fees for NICU	1054.21	1.00†	CRCR 03.05
Primary C-section, with induction	5730.00	77.58	CMG 558
Primary C-section, with no induction	4348.03	52.82	CMG 559
Vaginal birth with anaesthetic and non-major Obstetric/Gynecologic intervention	3476.28	62.01	CMG 562
Vaginal birth with anaesthetic without non-major Obstetric/Gynecologic intervention	2717.70	28.27	CMG 563
Vaginal birth without anaesthetic with non-major Obstetric/Gynecologic intervention	2586.40	33.08	CMG 564
Vaginal birth without anaesthetic without non-major Obstetric/Gynecologic intervention	1992.41	22.03	CMG 565
Normal newborn, singleton vaginal birth	889.42	5.50	CMG 576
Normal newborn multiple/caesarean birth	1343.33	14.53	CMG 577
Inpatient costs for NICU	5886.67	532.37	CMG 589-599
Forceps/vacuum birth	644.93	1.00†	OBST 84
C-section	644.93	1.00†	OBST 86.1
Average direct costs to a centre per visit	76.23	1.00†	
Physician Fees			
Initial visit with a complete examination	149.90	1.00†	VIST 03.03
Antepartum care	386.96	1.00†	VIST 03.03
Postpartum care (No NICU, mother and baby)	357.19	1.00†	VIST 03.03
Postpartum care (NICU, only mother)	79.38	1.00†	VIST 03.03
Spontaneous vaginal birth	496.10	1.00†	OBST87.98
Estimated midwifery cost per case¥	2863.25	572.65	

The codes are from the 2014 Nova Scotia Medical Services Insurance Physician Manual, retrieved from http://msi.medavie.bluecross.ca/wpcontent/uploads/sites/3/2015/07/PhysicianManual.pdf
† Assumed for probabilistic sensitivity analysis.
¥ The average yearly salary with benefits for midwives in Nova Scotia was C$ 91,624. On average, each midwife sees 32 cases per year. The average annual salary divided by the average number of cases gives a rough estimate of the cost per case. We assumed 20% of the cost per case as the standard error (SE) for sensitivity analysis.

Table 6
Probabilities used to parameterise the analytic decision model.

Variable	MW Probability (SE)	FP Probability (SE)	Conditions
Induction	0.228(0.050)	0.424(0.013)	Induction
Pain support	0.839(0.025)	0.947(0.006)	Pain support; induction
Spontaneous vaginal birth	0.781(0.019)	0.769(0.018)	Pain support; induction
Forceps/vacuum	0.083(0.010)	0.102(0.013)	Pain support; induction
NICU: SVB	0.067(0.006)	0.058(0.009)	Spontaneous vaginal birth; induction; pain support
NICU: FV	0.086(0.019)	0.062(0.009)	Forceps and or vacuum birth; induction; pain support
NICU: C-section	0.088 (0.019)	0.063(0.010)	C-section; induction; pain support
NICU: SVB_no pain support	0.067(0.007)	0.056(0.009)	Spontaneous vaginal birth; induction; no pain support
Pain support_noinduct	0.332(0.081)	0.791(0.011)	Pain support; no induction
Spontaneous_no induction	0.883(0.024)	0.789(0.019)	Spontaneous vaginal birth; pain support; no induction
Forceps/vacuum_no induction	0.047(0.011)	0.093(0.013)	Forceps and or vacuum; no induction; pain support
NICU: SVB_no induction	0.067(0.006)	0.059(0.009)	Spontaneous vaginal birth; no induction; pain support
NICU: FV_no induction	0.065(0.007)	0.059(0.009)	Forceps and or vacuum; no induction pain support
NICU: C-section_no induction	0.065(0.007)	0.059(0.009)	C-section; no induction; pain support
NICU: SVB_no induct_no ps	0.060(0.008)	0.050(0.008)	Spontaneous vaginal birth; no induction; no pain support

All probabilities were estimated from odds ratios from logistic models that control for confounders, with clustered standard errors, clustering at the level of birth hospital; SVB = spontaneous vaginal birth; FV = forceps and or vacuum; Ps = pain support; NICU = neonatal intensive care unit; FP = family physician; MW = midwife; OB/GYN = obstetrician/gynaecologist. SE = standard error. See Fig. 1.

Table 7
Cost-effectiveness results.

Parameter	Reference case		Probabilistic sensitivity analysis (PSA) ($N = 1000$ simulated cohort)	
	Midwife	Family physician	Midwife	Family physician
Expected costs (95% CI)	C$ 8,308	C$ 7,131	C$ 8,307(6945 to 10,000)	C$ 7,129 (7,011 to 7,262)
Expected NICU avoided (95% CI)	0.94	0.89	0.94 (0.93 to 0.95)	0.89 (0.88 to 0.91)
Difference, expected NICU avoided (95% CI)	0.04		0.04 (0.02 to 0.06)	
Difference, expected costs (95% CI)	C$ 1,177		C 2,914$ 1,176 (-221 to1196)	
ICER, (95% CI)	C$ 27,502		C$ 30,956 (−4,906 to 94,665)	
NMB at WTP of C$ 50,000, (95% CI)	C$ 963		C$ 9,58 (−1,152 to 2,844)	

The probability that MW is cost-effective at C$ 50,000/NICU avoided was 0.83.
NMB = the net monetary benefit; WTP = the willingness to pay; ICER = incremental cost-effectiveness ratio; CI = confidence interval; Difference = Midwife - Family physician.

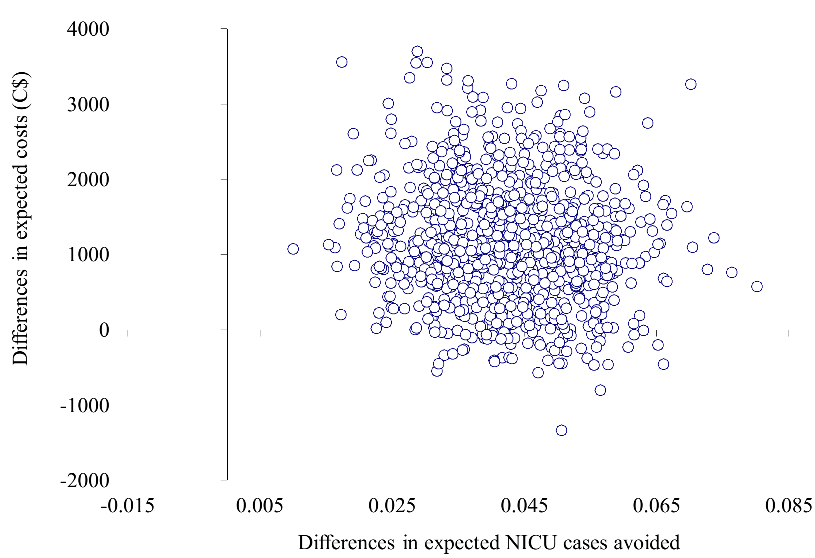

Fig. 2. Cost-effectiveness plane from the 1000 simulations. The probability that the midwifery program is cost-effective at a willingness-to-pay threshold of C$ 50,000 was 0.83 or 83%.

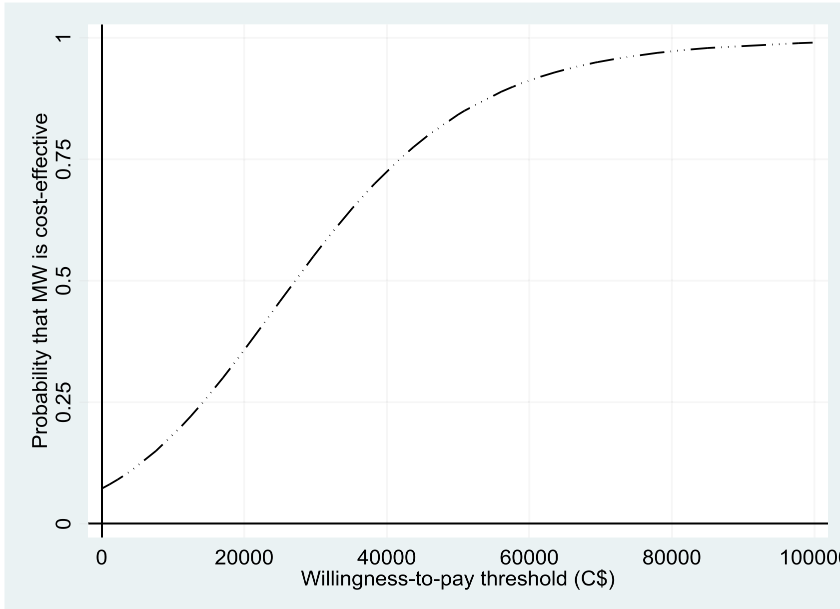

Fig. 3. Cost-effectiveness acceptability curve (CEAC) from the 1000 simulations.

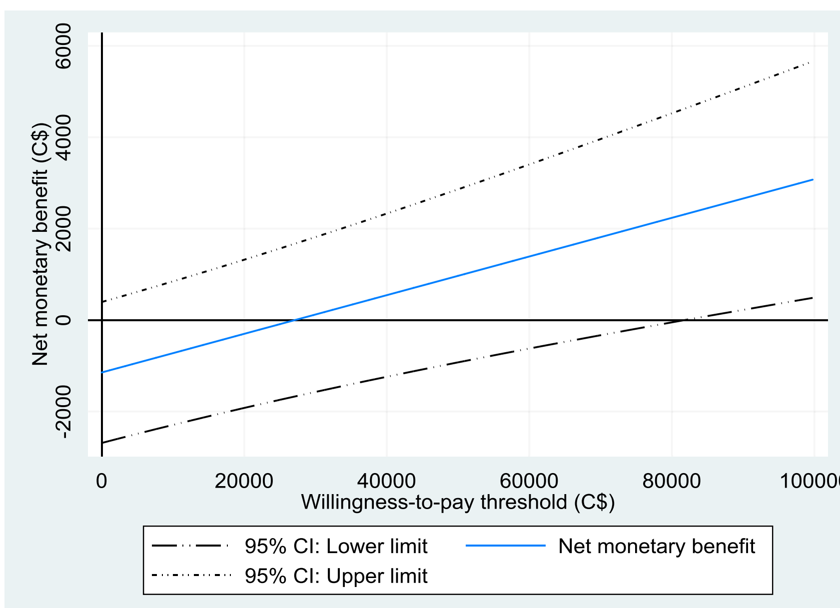

Fig. 4. Net monetary benefit with varying levels of WTP from the 1000 simulations.

which will decrease the average cost per case. Women in NS select service providers based on the availability of services in their geographical locations, and previous experience. Access to MLC involves a referral from a health care provider or completion of an application form, processed on a first come, first served basis. From a policy perspective, increasing the number of midwives could increase access at the community level.

The results reported in this study provide robust empirical support for the relative effectiveness and cost-effectiveness of the employee-model of MLC. While the sample was from a Canadian population, the results will nonetheless serve as valuable input into policy discussions on the role of midwives in improving women's access to health care both in developing and developed countries.

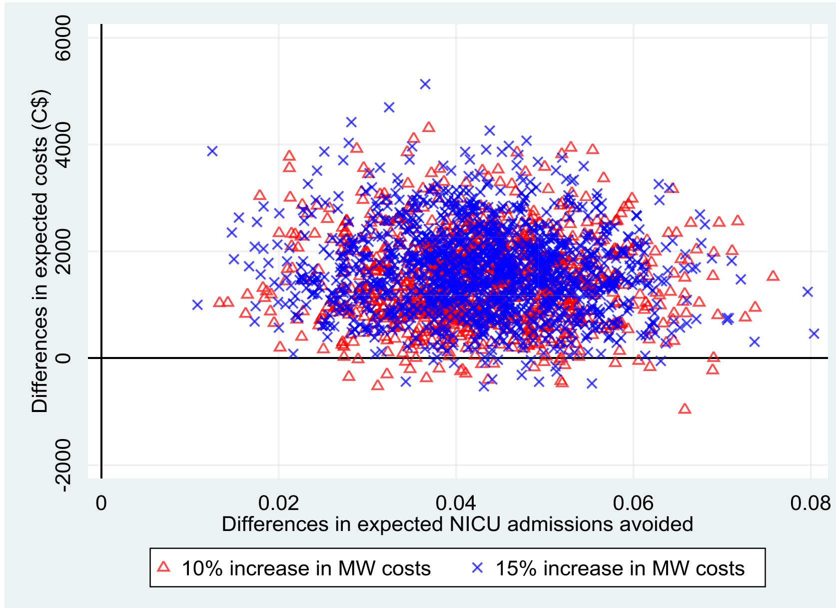

Fig. 5. Cost-effectiveness plane for MW cost increases. The probability that the midwifery program is cost-effective at a willingness-to-pay threshold of C$ 50,000 with a 10% increase in MW costs was 0.78 or 78%, and 0.69 or 69% with a 15% increase. See Table S4.

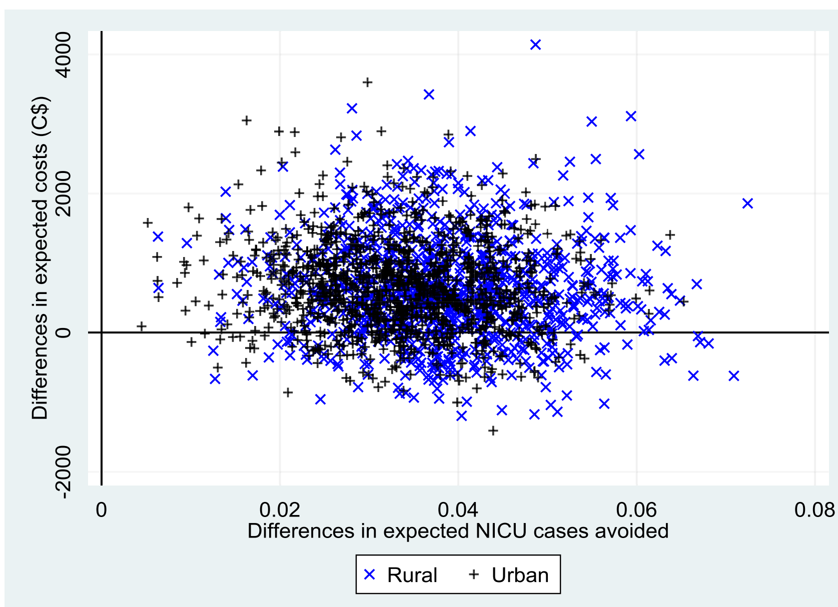

Fig. 6. Cost-effectiveness plane by location. The probability that the midwifery program is cost-effective at a willingness-to-pay threshold of C$ 50,000 in the rural (urban) subgroup was 0.91 or 91% (0.87 or 87%). See Table S6.

Conflict of interest

None declared.

Ethical approval

Approval from the Nova Scotia Health Authority and the Izaak Walton Killam Health Centre Research Ethics Boards.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.midw.2019.07.008.

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