Association between prenatal care and small for gestational age birth: an ecological study in Quebec, Canada

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Abstract

Background: In Quebec, women living on low income receive a number of additional prenatal care visits, determined by their area of residence, of both multi-component and food supplementation programs. We investigated whether increasing the number of visits reduces the odds of the main outcome of small for gestational age (SGA) birth (weight $< 10^{th}$ percentile on the Canadian scale).

Methods: In this ecological study, births were identified from Quebec's registry of demographic events between 2006 and 2008 (n = 156 404; 134 areas). Individual characteristics were extracted from the registry, and portraits of the general population were deduced from data on multi-component and food supplement interventions, the Canadian census and the Canadian Community Health Survey. Mothers without a high school diploma were eligible for the programs. Multilevel logistic regression models were fitted using generalized estimating equations to account for the correlation between individuals on the same territory. Potential confounders included sedentary behaviour and cigarette smoking. The odds ratios (ORs) were adjusted for mother's age, marital status, parity, program coverage and mean income in the area.

Results: Mothers eligible for the programs remain at a higher odds of SGA than non-eligible mothers (OR = 1.40; 95% confidence interval [CI]: 1.30–1.51). Further, areas that provide more visits to eligible mothers (4–6 food supplementation visits) seem more successful at reducing the frequency of SGA birth than those that provide 1–2 or 3 visits (OR = 0.86; 95% CI: 0.75–0.99).

Conclusions: Further studies that validate whether an increase in the number of prenatal care interventions reduces the odds of SGA birth in different populations and evaluate other potential benefits for the children should be done.

Keywords: *birth weight, gestational age, reproductive health, intervention, health behaviour*

Highlights

- This is the first observational study of Quebec's population – and one of the few worldwide – that explores the benefits of prenatal intervention along the gradient of intensity of available care.
- In Quebec, all pregnant women receive prenatal care. Women living on low income receive additional care through multi-component and food supplementation programs.
- Mothers eligible for the supplementation programs remain at a higher risk of small for gestational age (SGA) birth than non-eligible mothers.
- Prenatal care interventions provided to women living on low income are associated with lower odds of SGA birth.
- In addition, the authors observed a strengthening of the association with increasing number of interventions.

Introduction

Small for gestational age (SGA) birth is an indicator of fetal development[1] that takes into account fetal weight and length of gestation.[2] SGA is associated with neonatal death and chronic illness.[2,3] Determinants of this outcome include advanced maternal age, chronic disease of the mother, race/ethnicity, primiparity, nutritional status and lifestyle characteristics such as smoking, drug use and physical activity/workload.[2]

To date, participation in multi-component prenatal care programs has not been conclusively found to decrease risks of SGA birth, even among high-risk women.[4-8] However, participating in multi-component programs throughout pregnancy can improve parental behaviours and use of community-based resources.[5,9] Further, reducing use of tobacco—usually included in multi-component programs—is associated with decreased risks of low birthweight and preterm birth.[10]

Randomized controlled trials (RCTs) indicate that balanced energy and protein supplementation seem to reduce the

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occurrence of SGA birth.[11] However, what remains unclear is whether those results can be extrapolated to the whole population in a ''real world'' setting.[12-14] Indeed, compliance may be affected by researchers' investment in the intervention, and women participating in such studies may be more prone to changing their behaviour.[12-14] An observational design could be used to gain further insights on prenatal care intervention. Results from such a study should be adjusted for confounders such as age, poverty and availability of care because it does not include a randomization process that itself controls for confounding.[4,15]

In Quebec, standard prenatal care is provided by physicians, and additional support is provided by nurses, social workers and nutritionists as part of the integrated perinatal and toddler services multi-component care program (SIPPE)[16] and as part of the egg, milk and orange food supplementation program[17,18] (further information available on request from the authors). In-home multi-component visits include self-empowerment, emotional support and education to improve dietary habits and reduce sedentariness, tobacco use, alcohol consumption and recreational drug use.[16,*]

Both programs are standard care for women at a higher risk of pregnancy complications because they are young or living on low income.[16,17] The participants are mostly referred to additional care through their prenatal clinic, their medical clinic or their local community health centre, although some contact their local community health centre themselves to indicate their need for intervention.[17] The Centres locaux de services communautaires (local community service centres; CLSC) manage these programs.

RCTs suggest that multi-component interventions are effective at improving maternal diet, emotional support and mental health.[16] The intensity of the interventions (the number of visits provided) and program coverage (the proportion of high-risk mothers receiving effective intervention) has been identified as an important consideration when evaluating intervention.[19] However, what remains unknown is the intensity of the multi-component or food supplementation interventions required to lower the frequency of SGA birth.[20,21]

We speculated that increasing the number of visits reduces the odds of an SGA birth. To test this hypothesis, we investigated whether the average number of additional care visits in areas of residence in Quebec, Canada, had a dose–response association with SGA births.

Methods

Study population and setting

This is an observational study (ecological analytic multiple-group design) of the live singleton births registered in Quebec's registry of demographic events (Registre des événements démographiques du Québec) from April 2006 through March 2008 (n = 156 404 births).[22] Participants' areas of residence were determined from data on prenatal support interventions (n = 134 CLSCs), the Canadian census of 2001 and 2006 and the Canadian Community Health Survey (CCHS) of 2001, 2003, 2005, 2007 and 2008.[23] These years were chosen to build a portrait of the environment before and during pregnancy.

Quebec's registry of demographic events collects information on every live birth and on the mother (birth weight, gestational age, mother's age, academic degree and postal code). Between 2006 and 2008, 8.1% (99% confidence interval [CI]: 8.1–8.3) of births in Quebec were SGA whereas between 2009 and 2011 this proportion had risen to 8.6% (99% CI: 8.4–8.7).[24]

Data on prenatal support interventions available at the CLSC level (number of interventions provided by CLSC per year) can be found in the ''Info-CLSC'' system.[25] CLSCs vary in size (mean population: n = 46 727; mean births per year: n = 389).

The 2001 and 2006 censuses include data on mean income as well as information on the urbanity and rurality of neighbourhoods within areas. The CLSC portraits were built by pooling area data by the number of residents. Census area geographies were linked to CLSC geographies by merging the federal file ''Fichier de conversion des codes postaux plus'' (which included the dissemination area and postal code) to Quebec's health geography ''Référentiel territorial M34'' (postal code and CLSC territory) by postal code.

The CCHS includes information about food insecurity, tobacco use, sedentary behaviour and low social support. Data from Quebec's residents from the different cycles (2001, 2003, 2005, 2007 and 2008) were pooled and CLSC proportion-like values were built using the 100 832 CCHS responses.

The CLSC portraits of the general population were associated with the mothers' variables using their postal codes.[24] If a postal code did not exactly match a CLSC boundary (which occurred for fewer than 3% of the codes), it was associated with the CLSC territory that included the majority of the residents. Table 1 shows individually measured information and CLSC-level variables.

Excluded were births at less than 22 weeks gestational age or more than 43 weeks gestational age; with implausible weight for age (according to a criteria recommended by Alexander et al.[26]); with missing potential confounder information at the CLSC level (births from CLSCs of the Nord-du-Québec, Terres-Cries-de-la-Baie-James and Nunavik regions); and with missing data on prenatal care.

[*] Interventionists in the multi-component care programs are mostly nurses. They first evaluate whether the family's primary needs are met, paying special attention to nutrition, housing and security of every member of the family. If problems such as violence or drug abuse are present, additional help is provided. Nurses also inform families about community activities that might be of use.[15] Coupons for eggs, one litre of 3.25% milk, 125 millilitres of orange juice, and multivitamin and mineral supplements are provided to women on low income. A nurse or a nutritionist also visits the women as part of this program. Other professionals intervene when required.[16]

TABLE 1
Data sources and variables related to Quebec births, 2006–2008

Data		Variable
Explanatory variables		
CLSC level	Data on prenatal support, MSSS	Intensity of interventions: • non-eligible mother • mother eligible for both programs[a] Average number of food interventions per eligible woman: ○ lowest/1–2 visits from the food supplementation program ○ medium/3 visits ○ highest/4–6 visits
Potential confounders		
Individual-level	Registry of demographic events, MSSS[b]	Mother's country of birth
		Marital status
		Parity
		Academic qualification
CLSC level	Canadian Community Health Survey, Statistics Canada[c]	Percentage of residents with food insecurity in the past 12 months[d]
		% of residents with sedentary behaviour in the past 3 months[d]
		% of residents with low tangible social support on the Medical Outcome Study subscale[d]
		% of residents who smoke cigarettes daily[d]
	Canadian census, Statistics Canada[e]	Presence of urban neighbourhoods within the CLSC (exclusively urban; exclusively rural; urban and rural neighbourhoods)
		Mean income
Individual-level	Registry of demographic events, MSSS	Mother's age, years ($<$ 20; 20–24; 25–29; 30–34; $\geq$ 35)
CLSC level	Data on prenatal support, MSSS[e]	Programs coverage[f] (% of target population receiving food intervention)

Abbreviations: CLSC, Centres locaux de services communautaires (local community health centre territory); MSSS, Ministère de la Santé et des Services sociaux du Québec.

[a] Mother has $<$11 years of education.

[b] April 2006 through March 2008.

[c] Survey cycles were pooled (2000–01, 2003, 2005, 2007–08).

[d] Value calculated for $\geq$ 12-year-olds. Excludes survey cycle and data collection method effects.

[e] 2001 and 2006.

[f] This variable was incorporated in the definition of the "intensity of intervention."

Variables

Outcomes

The main outcome was SGA birth (weight below the 10th percentile of the Canadian reference scale).[1] The ''term births only'' population was used for sensitivity analyses (births were categorized as ''term births'' using the registry of demographic events).

Exposure

Both multi-component and food intervention programs targeted women in need. Mothers targeted by the food supplementation program had a family income below the Canadian cut-off.[†] Those targeted by multi-component interventions were less than 20 years old at the estimated time of birth, had no high school diploma or had a low family income.[16,18]

Mothers without a high school diploma were considered eligible for both the multi-component and the food programs, since this population has the lowest income (on average, in 2009, women with a high school diploma or less earned $20,400 per year, those with college degree earned $30,300 and those with a university degree earned $48,400[27]). We used a narrower definition of eligibility (mothers aged less than 20 years and without a high school diploma) for sensitivity analyses, as younger women are more likely to have a low household income.[28]

The intensity of the multi-component or food supplementation intervention received by eligible women was an area-level variable. It was neither directly measured for every woman nor based on whether they receive the intervention; it was based on whether mothers *could* receive the intervention. It corresponded to the average number of visits from the food supplementation program per eligible

[†]The low income cut-offs are income thresholds below which a family will likely spend a larger share of its income on the necessities of food, shelter and clothing than the average family. This approach essentially estimates an income threshold at which families are expected to spend 20 percentage points more than the average family on food, shelter and clothing. Twenty percentage points are used on the rationale that family spending 20 percentage points more than the average would be in "straitened circumstances."

woman living in the CLSC territory (those women also had between 2 and 8 multi-component visits). The number of visits from the food supplementation program were categorized into tertiles (lowest: 1 to 2 visits; medium: 3 visits and highest: 4 to 6 visits). Non-eligible mothers were given an intensity of exposure equal to zero and were included in the ''non-eligible for the program/reference'' category (Table 1).

Potential confounders

Potential confounders are program eligibility and individual maternal characteristics (age, country of birth, marital status, academic qualification and parity) at the individual-level and program coverage as well as variables portraying residents of the CLSC territories at the CLSC level.

CLSC defined program eligibility and program coverage variables as follows: mothers without a high school diploma were identified as eligible for the food supplementation program and the multi-component program. This variable was incorporated in the definition of the ''intensity of intervention.'' Program coverage was calculated as the proportion of eligible mothers receiving intervention on the CLSC territory. A categorical scale was used for univariate analyses (''non-eligible,'' ''lowest,'' ''medium'' and ''highest'').

Other CLSC ''portraits'' included the proportion of urban neighbourhoods within each CLSC territory (''exclusively urban neighbourhoods/reference,'' ''exclusively rural neighbourhoods'' and ''urban and rural neighbourhoods''); mean income (''lowest,'' ''medium'' and ''highest/reference''); proportion of residents with the following risk factors: food insecurity, sedentary behaviour, low tangible social support and daily tobacco use (using ''lowest/reference,'' ''medium'' and ''highest'' tertiles).

Source of data

Mothers and their babies were registered in the registry of demographic events by the Ministère de la Santé et des Services sociaux du Québec (April 2006 through March 2008). Their CLSCs were portrayed by the same dataset on prenatal support interventions, by data from the Canadian census from Statistics Canada (2001 and 2006) and by the CCHS from Statistics Canada (the 2001, 2003, 2005, 2007 and 2008 files were combined to achieve a reasonable number of respondents per CLSC).[22] CLSC portraits were associated with maternal variables using postal codes, as described elsewhere.[24] Table 1 shows additional information related to the variables used.

Statistical analysis

All data have a multilevel structure: the first level is the mother and the second is the local community health centre.[29] Multilevel logistic regression models were fitted using generalized estimating equations (GEE) to account for the correlation between individuals in the same CLSC territory. (The GEE method provides consistent odds ratio [OR] estimates for the population even though the correlation between mothers from the same CLSC is unknown.) We used independent working correlation structures throughout the univariate and multivariate analyses and obtained empirical robust standard error estimates.[30]

Univariate logistic regression models were fitted on every potential confounder and on exposure (dependent variable: SGA birth). Multivariate models were fitted on exposure. A full model was first adjusted with all the potential confounders listed in Table 2. Confounders that changed the effect estimate of the exposure by less than 5% were removed one at a time (change-in-estimate approach[31,32]), which resulted in the final adjusted model.

Sensitivity analyses were as follows: regressions of SGA on intensity using term births only (from 37 to 40 weeks of gestational age inclusively) and regressions of SGA on intensity using the narrower definition of eligibility for the programs (mothers aged less than 20 years without high school diploma). Both analyses were adjusted for confounders incorporated in the final model.

Analyses were carried out using SAS version 9.2 (GENMOD and REG procedures). Results were considered statistically significant at $p < .05$.

The Commission d'accès à l'information du Québec and Université Laval's Ethics Committee approved this research project.

Results

Participants

A total of 156 404 singleton births (134 CLSCs) were included. Most of the mothers were 25 to 29 years old, had a university degree, were born in Canada, were primiparous and unmarried (neither married nor in a common-law relationship) (Table 2). A total of 11.1% of the 10 742 eligible births and 8.1% of the non-eligible births were SGA. (Further information on program coverage is available from the authors on request.)

Univariate regression analyses

Mothers aged less than 20 years (OR = 1.46; 95% CI: 1.32–1.61) and 20 to 24 years (OR = 1.23; 95% CI: 1.17–1.29) have higher unadjusted odds of SGA while 30- to 34-year-old mothers have a lower odds (OR = 0.88; 95% CI: 0.85–0.92) compared to 25- to 29-year-old mothers (the reference category). Mothers with less than a high school diploma (OR = 1.31; 95% CI: 1.26–1.37) and those with a high school diploma (OR = 1.56; 95% CI: 1.44–1.69) had higher odds of SGA than mothers with a university degree. Mothers born outside Canada (OR = 1.18; 95% CI: 1.09–1.29), primiparous mothers (OR = 1.82; 95% CIs: 1.75–1.89) and unmarried mothers (OR = 1.14; 95% CIs: 1.06–1.23) also had higher odds of SGA compared to mothers from the reference categories.

Mothers from CLSCs with a medium (OR = 1.10; 95% CI: 1.00–1.21) or high proportion (OR = 1.19; 95% CI: 1.10–1.28) of residents experiencing food insecurity, a high proportion of sedentary residents (OR = 1.16; 95% CI: 1.06–1.27) and a high proportion of residents who smoke cigarettes (OR = 1.10; 95% CI: 1.01–1.21) have higher odds of SGA than mothers from CLSCs with low proportions of these variables. Mothers from

TABLE 2
Unadjusted odds ratios of SGA births, N = 156 404 births, 2006–2008, Quebec, Canada

Individual-level variable from Registry of demographic events	Number and proportion of live births, n (%)	Proportion of SGA births, %	Crude odds ratio (95% CI)	*p* value
Mother's age, years				< .01
< 20	4049 (2.6)	11.6	1.46 (1.32–1.61)	
20–24	23 767 (15.2)	10.0	1.23 (1.17–1.29)	
25–29 (reference category)	56 170 (35.9)	8.3	1.00	
30–34	48 981 (31.3)	7.4	0.88 (0.85–0.92)	
≥ 35	23 437 (15.0)	8.2	0.99 (0.93–1.05)	
Academic qualification				< .01
< High school	10 742 (6.9)	11.1	1.56 (1.44–1.69)	
High school diploma	46 660 (29.8)	9.5	1.31 (1.26–1.37)	
College	44 048 (28.2)	7.5	1.02 (0.98–1.06)	
≥ University (reference category)	54 954 (35.1)	7.4	1.00	
Mother's country of birth				
Other	31 350 (20.0)	9.4	1.18 (1.09–1.29)	
Canada (reference category)	125 054 (80.0)	8.1	1.00	
Parity				
Primiparous	72 792 (53.5)	10.8	1.82 (1.75–1.89)	
Multiparous (reference category)	83 612 (46.5)	6.2	1.00	
Marital status				
Married (reference category)	59 038 (37.8)	7.7	1.00	
Unmarried	97 366 (62.3)	8.7	1.14 (1.06–1.23)	

Abbreviations: CI, confidence interval; CLSC, Centres locaux de services communautaires (local community health centre territory); SGA, small for gestational age.

CLSCs with the lowest mean income have higher odds of SGA than mothers from CLSCs with the highest mean income (OR = 1.18; 95% CI: 1.09–1.28). Finally, mothers from CLSCs with both urban and rural neighbourhoods have lower odds of SGA than mothers from rural CLSCs (OR = 0.92; 95% CI: 0.84–1.00) (Table 3).

Crude OR estimates from regression on intensity indicate that eligible mothers from any of the ''lowest: 1 to 2 visits from the food supplementation program,'' ''medium: 3 visits'' and ''highest: 4 to 6 visits'' categories have higher odds of SGA than non-eligible mothers (OR = 1.40; 95% CI: 1.30–1.51; not shown in the table).

Multivariate regression analyses

Results of crude and adjusted odds ratios of SGA are shown in Table 4. The final adjusted model on intensity accounts for mothers' age, parity and marital status as well as program coverage and mean income in the CLSC. Women eligible for both multi-component and food intervention from any of the intensity groups had higher adjusted odds of SGA than non-eligible women (OR = 1.40; 95% CI: 1.30–1.51; data not shown). Moreover, the association with increasing intensity of interventions was attenuated: eligible women living in a territory that provided high-intensity interventions (4–6 visits of food intervention per eligible woman) had lower odds of SGA than women living in a territory that provides interventions of low or medium intensity (1–2 or 3 visits per eligible woman) (OR = 0.86; 95% CI: 0.75–0.99; data not shown). Estimates from the full models are similar to those from the adjusted models (not shown in the table).

Sensitivity analyses corroborate the main results. When the final models were fitted on term births only, mothers eligible for the programs had a greater odds of SGA than non-eligible mothers (OR: 1.43; 95% CI: 1.32–1.55; data not shown), while high exposure is associated with lower odds than low or medium exposure (OR = 0.90; 95% CI: 0.78–1.05; data not shown). Final results on data with the narrower definition of eligibility for intervention were also similar. The eligible mothers have a greater odds of SGA than the non-eligible (n = 147 156) mothers (OR = 1.48; 95% CI: 1.36–1.60; data not shown). There were fewer eligible mothers (n = 9248) when this definition is used than when the definition based on academic qualification alone (10 742 eligible mothers) was used. Final results are similar but non-significant (OR = 0.89; 95% CI: 0.76–1.04; data not shown).

Discussion

This is the first observational study of Quebec's population—and one of the few worldwide—that explores the benefits of prenatal intervention along the gradient of intensity of available care. We found that mothers living in Quebec who are eligible for supplemental prenatal care programs are at a higher odds of SGA than those who are non-eligible, and that prenatal care interventions provided to women living on low income are associated with lower odds of SGA birth. In

TABLE 3
Unadjusted odds ratios of SGA births, N = 156 404 births, 2006–2008 Quebec, Canada

CLSC level by tertile[a]		Population of live births, n (%)	Proportion of SGA births, %	Crude odds ratio (95 % CI)	*p* value
Proportion of the target population receiving food intervention[b]					<.01
Non-eligible mother (reference category)		145 662 (93.1)	8.1	1.00	
Lowest	0.0–100.0	4607 (3.0)	11.3	1.44 (1.28–1.61)	
Medium	100.0–200.0	3680 (2.4)	10.9	1.38 (1.25–1.52)	
Highest	200.0–700.0	2455 (1.6)	11.3	1.44 (1.28–1.61)	
Proportion of residents in the CLSC with food insecurity, %[c]					<.01
Lowest (reference category)	4.0–10.5	52 260 (33.4)	7.7	1.00	
Medium	10.6–15.1	57 488 (36.7)	8.4	1.10 (1.00[d]–1.21)	
Highest	15.2–36.4	46 656 (29.8)	9.0	1.19 (1.10–1.28)	
Proportion of sedentary residents, %[c]					
Lowest (reference category)	1.7–9.9	50 076 (32.0)	7.8	1.00	
Medium	9.9–14.4	48 360 (30.9)	8.2	1.06 (0.98–1.15)	
Highest	14.4–31.0	57 968 (37.1)	8.9	1.16 (1.06–1.27)	
Proportion of residents with low tangible social support, %[c]					.06
Lowest (reference category)	12.1–37.8	38 421 (24.6)	8.0	1.00	
Medium	37.8–47.2	65 141 (41.7)	8.8	1.11 (1.02–1.20)	
Highest	47.2–69.9	52 842 (33.8)	8.1	1.01 (0.93–1.10)	
Proportion of residents who smoke cigarettes daily, %[c]					.04
Lowest (reference category)	8.1–20.8	64 511 (41.3)	8.1	1.00	
Medium	20.8–25.9	51 439 (32.9)	8.2	1.02 (0.93–1.11)	
Highest	25.9–39.4	40 454 (25.9)	8.9	1.10 (1.01–1.21)	
Mean income[c]					<.01
Lowest	$16,144–$25,268	25 964 (16.6)	8.0	1.18 (1.09–1.28)	
Medium	$25,268–$28,797	53 052 (33.9)	8.3	1.04 (0.96–1.12)	
Highest (reference category)	$28,797–$47,610	77 388 (49.5)	9.3	1.00	
Presence of urban and rural neighbourhoods in the CLSC[c]					.05
Rural		32 246 (20.6)	8.3	1.00	
Urban and rural		35 346 (22.6)	7.7	0.92 (0.84–1.00[e])	
Urban		88 812 (56.8)	8.6	1.03 (0.96–1.11)	

Abbreviations: CI, confidence interval; CLSC, Centres locaux de services communautaires (local community health centre territory); SGA, small for gestational age.

[a] CLSC-level variables were linked to birth data by postal codes.

[b] 3% of the births were in the lowest tertile (0%–100%) and received 1 to 2 visits from the food supplementation program, 4% were in the medium tertile (100%–200%) receiving 3 visits, and 4% were on the highest tertile (200%–700%) receiving 4 to 6 visits. More than 57% of the eligible mothers were in a CLSC with a rate of access to food intervention equal to or above 100%. Those women also had access to the multi-component intervention.

[c] 134 CLSC territories were included.

[d] Value > 1.00.

[e] Value < 1.00.

addition, we observed a strengthening of the association with increasing intensity of the interventions. However, interventions do not counteract all of the effects associated with need; eligible mothers remain at higher odds of SGA than non-eligible mothers. Nevertheless, the interventions have some effect: areas that provide high-intensity intervention (4 to 6 visits from the food supplementation program) reduce the frequency of SGA birth more successfully than those that provide low- or medium-intensity intervention.

Though results from RCTs on the subject were encouraging, experimental studies on dietary changes have numerous limits[12-14] and an observational study provides needed confirmation. Our odds ratio of SGA for high- versus medium- or low-intensity intervention is similar to the pooled relative risk (RR) from RCTs on balanced energy/protein supplementation (6 studies; n = 3396; RR = 0.68; 95% CI: 0.56–0.84).[11]

Our findings on high- versus medium- or low-intensity interventions (OR = 0.86;

TABLE 4
Association of intensity of intervention with SGA births, N = 156 404 births, 2006–2008, Quebec, Canada

Intervention (CLSC level)[a]		Births, n (%)	Proportion of SGA births, %	Association of intensity of intervention	
				Crude OR (95% CI)	Adjusted OR[b] (95% CI)
Non-eligible mother[c]		145 662 (93.1)	8.1	1.00	1.00
Lowest tertile	(1–2 visits)	3611 (2.3)	11.7	1.50 (1.33–1.69)	1.49 (1.32–1.69)
Medium tertile	(3 visits)	4233 (2.7)	11.3	1.44 (1.30–1.60)	1.46 (1.32–1.61)
Highest tertile	(4–6 visits)	2898 (1.9)	10.2	1.29 (1.13–1.46)	1.27 (1.12–1.44)

Abbreviations: CI, confidence interval; CLSC, Centres locaux de services communautaires (local community health centre territory); SGA, small for gestational age.

[a] Number of visits is an area-level measure.

[b] Results account for mother's age, parity, marital status as well as food intervention program coverage (continuous) and mean income in the CLSC.

[c] Mothers with a high school degree are in the "non-eligible" category. They could still have received food intervention if their family income is low.

95% CI: 0.75–0.99) are comparable to those in more controlled studies compiled in a review of experimental and observational studies:[4] associations with low birth-weight were within the acceptable range (0.80–0.90). International meta-analyses of RCTs on the impacts of multi-component intervention among high-risk women indicate similar and non-significant improvement in low birth-weight (11 studies; n = 8681; RR = 0.92, 95% CI: 0.83–1.03).[7]

Strengths and limitations

This study has a number of important strengths. It included the entire population of mothers and single births in Quebec; in other words, all women eligible for the supplementation programs. To the best of our knowledge, this is the first population-based study that statistically tests for differences in benefits according to program eligibility and on the gradient of exposure to intervention. Further, this is the first investigation of prenatal programs that assesses the relevance of accounting for the contextual factors of income, food insecurity, social support, smoking and sedentary behaviour. In addition, the use of external survey data to incorporate such contextual variables has never been done in the field of intervention. Understanding the benefits of exposure to prenatal care programs on SGA births provides unique insights for tailoring further interventions.

Some limitations should be considered when interpreting the results, including three possible ways to misclassify exposure to intervention. First, eligibility status was determined by a proxy, academic qualification because information on income was unavailable. Moreover, all the eligible women did not necessarily use the interventions. However, this bias is likely to have only a small impact on the results since the sensitivity analysis with the narrower definition of eligibility status led to similar associations with SGA.

Second, we assumed that the need for prenatal care and the intensity of use within CLSC territories remained constant over the years. Most women were exposed to the intensity of care we attributed to them, as intensity was averaged for the duration of the study.

Finally, we did not have information about the exposure to intervention of mothers who relocated. These misclassifications contributed to small biases towards the null association. Confounding potentially brought some bias to the association, as individual information such as a mother's chronic disease was not accounted for. If there were more women with a chronic disease eligible for intervention in CLSC territories with high-intensity intervention than in territories with low-intensity intervention, there would be another bias towards the null effect.

Defining what constitutes "high" exposure and whether this level of exposure is sufficient is difficult, and definitions are likely to vary between jurisdictions. Nonetheless, the categories we use in this study are based on a scale that can be used in the absence of knowledge on the subject.[28]

In terms of limitations, associations based on aggregate data (information on intensity of intervention based on data from the CLSCs) are weakened by the potential for ecological fallacy.[22] In addition, it was not possible to compare our results to the occurrence of SGA before the beginning of the intervention in this population.

An alternative explanation of the results could be that the CLSCs that provide high-intensity interventions have similar resources for fewer targeted women. Quality and timing of interventions could thus be maximized and their impact on SGA could be greater.

Conclusion

Significant differences along the gradient of care suggest that strategies that provide pregnant women with high exposure to interventions are effective at reducing the risk of SGA. The results have important implications for continuing existing programs and developing new ones adapted to the different needs of mothers. Numerous other benefits might be identified, as interventions do not result only in increasing weight for gestational age at birth.

Although results are encouraging, further research is needed on other subpopulations that could benefit from interventions. Future studies might benefit from incorporating some measure of the quality of

interventions, use of standard prenatal care and use of additional prenatal support.

Conflict of interest

The authors declare that they have no competing interests.

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