Effects of structured education and a physical activity prescription during prenatal care on maternal and fetal outcomes: A quasi-experimental study

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Abstract

Background: Physical activity (PA) during pregnancy is associated with healthy gestational weight gain (GWG) and a reduction in risk of developing gestational diabetes (GD), hypertension (GHT) and fetal macrosomia. However, less than 20% of pregnant women meet the PA recommendations in Canada. We tested the effects of PA education and a PA prescription by prenatal nurses and physicians on fetal and maternal outcomes.

Methods: Administrative data from two periods with distinct prenatal care offering were used. In the first period, 394 pregnant women followed at the obstetrics clinic of a university hospital received standard care whereas 422 women followed in the second period received standard care supplemented with education on the relevance of PA during pregnancy and a prescription for PA. Logistic regressions were used to compare odds of excessive GWG, GD, GHT, and fetal macrosomia between the two study groups.

Results: The addition of PA education and PA prescription to prenatal care was associated with a 29% reduction in odds of excessive GWG (adjusted OR 0.71, 95% CI 0.51-0.99), 73% reduction in odds of GHT (0.27, 0.14-0.53) and 44% reduction in odds of fetal macrosomia (0.56, 0.34-0.93). The intervention was not associated with different odds of GD (0.48, 0.12-1.94).

Conclusions: The inclusion of education and prescription of PA as part of routine prenatal care can lead to significant improvements in maternal and fetal health outcomes.

Background

It is recommended that pregnant women participate in 150 minutes of PA per week to prevent excessive gestational weight gain (GWG) (1, 2), gestational diabetes (GD), gestational hypertension (GHT) and fetal macrosomia (1, 3). Nevertheless, fewer than two in ten pregnant women adhere to this recommendation in Canada (4). Similar to other developed countries (5), approximately 50% of pregnant women gain more than the recommended weight during pregnancy in Canada (6). Excessive GWG is associated with an increased risk of adverse obstetric effects which are harmful to maternal and fetal health outcomes (5, 7). For the mother, excess GWG increases the risk of having GD (8), GHT (9), a C-section (10), premature birth (11), development of excess weight, and obesity (7). In neonates, excessive GWG increases the incidence of macrosomia (10, 11) and stillbirth (8).

The marked increase in the incidence of GD over the past 20 years has been attributed to increasingly sedentary behaviors and rising obesity rates (12). In Canada, one in ten pregnant women has GD (13). Undiagnosed or untreated GD increases the risk of maternal and perinatal morbidity (14, 15). In the mother, GD increases the risk of GHT (14), preeclampsia (16), excess maternal weight (17), premature birth, having a C-section, developing GD in future pregnancies (14), and type 2 diabetes in the years following delivery (14, 18) or later in life (14, 16). For the infant, GD increases the risk of macrosomia, fetal malformations (15), birth trauma (18), obesity and childhood diabetes (14), glucose intolerance in early adulthood (19), and stillbirth (16).

In Canada, approximately 10% of pregnant women have GHT (20), the leading cause of maternal and fetal morbidity and mortality (21–23). GHT increases the risk of chronic high blood pressure, cardiovascular accidents (22, 24), and diabetes (23). Severe arterial hypertension during pregnancy can prompt complications such as heart or kidney failure, hypertensive encephalopathy, aortic dissection, or stroke (24). For the fetus, GHT can lead to intrauterine growth restriction, low birth weight, and premature birth (23).

Macrosomia affects 10% of newborns in Canada (25) and is associated with poorer health status throughout life (26). It increases the incidence of fetal and maternal mortality and morbidity (27). For the mother, it can result in difficult and occasionally traumatic vaginal delivery (28) or an emergency C-section (27, 16, 29). Macrosomic newborns are at increased risk for excess weight and obesity in childhood and adulthood (30), hypertension, adult ischemic heart disease, type 2 diabetes, and cancer in childhood and adulthood (31).

To prevent all of these conditions, several studies have reported that individualized personalized interventions (32–35) including information sharing (35), counseling (32, 34) and individual education (33), in particular, education by nurses (33) and counseling by physicians (34), appear to be effective in promoting PA. Personalized education allows information to be tailored to the needs of individuals and thus increases knowledge and enhances motivation related to PA (33). Physician advice is also perceived as being highly respected and can positively contribute to changes in patients' PA levels (36–38). Randomized controlled trials (39, 40) and systematic reviews (41, 42) have shown that prescribing PA is associated with a significant increase in PA behaviors, even in patients who were initially sedentary (39, 40) and patients who were not initially motivated to change their behaviors (39). However, the effectiveness of PA prescriptions in during prenatal care has not yet been evaluated.

The transtheoretical model suggests tailoring behavioral interventions based on the individual's stage of behavior change (43, 44). According to this model, individuals may progress through five stages of behavior change including: precontemplation, contemplation, preparation, action, and maintenance. Tailored interventions for each stage increase the likelihood of perceiving positive PA change (45–48).

Despite the available evidence supporting the promotion of prenatal PA to provide health benefits to the mother and her child, the most effective means to prevent certain maternal and fetal outcomes is still unclear (49). Particularly, although the combination of education and prescription of personalized PA according to behavior change stages seems promising to prevent GWG, GD, GHT, and macrosomia, its effectiveness remains uncertain. The objective of the study is to examine the effectiveness of a simple intervention, combining education by a nurse and personalized PA prescription by a physician, that can be integrated into the regular setting of a pregnancy follow-up clinic. The primary outcome is the prevention of excessive GWG, and the secondary outcomes are the prevention of GD, GHT, and fetal macrosomia. Specifically, we tested the hypotheses that, in comparison to pregnant women who received standard care, those who also received education and a PA prescription are more likely to complete their pregnancies with optimal GWG, lower incidence of GDM and HTG, and to deliver healthy birth weight infants.

Methodology

Study design

This quasi-experimental study was conducted under regular practice conditions of an obstetric clinic. The methodological approach used was to compare the maternal and fetal outcomes of a group of pregnant women who were followed during a period when the obstetric clinic offered standard care, with the outcomes of a group who were exposed to an enhanced care offer including education and prescription of PA during pregnancy. The study was approved by the human research ethics board of the health institution where the study was conducted and by the research ethics board of the *Université de Moncton*.

Participants

All pregnant women who had a follow-up at the Obstetrics Clinic of the Dr. Georges-L.-Dumont University Hospital Center (DGLDUHC) in Moncton, Canada were eligible. At this clinic, the first visit is at approximately 12 weeks of pregnancy, with subsequent visits every four weeks until 32 weeks, then every two weeks until 36 weeks of pregnancy, and then every week until delivery. Pregnant women are monitored by nurses who specialize in prenatal care, delivery physicians, and obstetrician-gynecologists. Women who were recruited to participate in the study received care at the maternity clinic before the 16th week of gestation, understood and spoke English or French, were 18 years of age or older, and were pregnant with a single baby. Women with eating disorders and pregnancy-related complications or general medical conditions not associated with pregnancy (determined by a physician) requiring specialized maternity care were excluded from the study.

All women whose pregnancy follow-up began after April 2019 were exposed to the enhanced care offer. Within 48 hours of delivery, these women were asked to provide consent for the research team to review their medical records and those of their babies to collect data relevant to this study. For the comparison group, the records of all women who were followed at the obstetric clinic in the year prior to the offer of enhanced care were considered.

Intervention

Nurses were trained to offer standardized education to pregnant women. Specifically, nurses were to provide information to pregnant women at the first prenatal visit about PA guidelines, the benefits of PA, recommendations related to GWG, and the consequences of excessive GWG, GD, GHT, and fetal macrosomia on maternal and fetal health. An explanatory brochure designed for this project was used to help standardize care and was given to women as a quick reference tool. During the first visit, nurses also asked pregnant women to answer a question identifying their stages of behavior change according to the transtheoretical model (50). Individual weight gain recommendations based on body mass index (BMI) according to the Institute of Medicine (IOM) were discussed at the first prenatal visit and monitored by nurses at every subsequent visit until the 37th week of gestation. For individualized follow-up of GWG and to guide the participant in monitoring her GWG, weight gain information was captured on a personalized chart with marked intervals of recommended weight (51). The education session with a nurse was followed by a personalized PA prescription written to the pregnant woman by a physician. Physicians were previously trained in PA prescribing according to the model developed by the group Exercise is Medicine Canada (52). They were also provided with suggested strategies and advice for each stage of behaviour change in the transtheoretical model. Physicians considered the stage of change of the pregnant woman to tailor their prescription.

At their first visit to the obstetric clinic, women in both study groups received written and oral information about dietary recommendations for pregnant women based on Canada's Food Guide and “Healthy Pregnancy... Healthy Baby - A New Life” (53). Among other things, the nurses stress the importance of regular meals, snacks, multivitamins, foods that contain iron, folic acid, omega-3 fats, and fiber. Nurses also discussed foods to limit such as low-nutrient foods, fried foods, artificial sugar, and caffeine.

Maternal and fetal outcomes

Socio-demographic data and data on each of the study outcomes are routinely collected by nurses in the obstetric and gynecological clinic. Pre-pregnancy weight is self-reported by the pregnant woman during her first clinic appointment. Thereafter, the woman's weight is taken and recorded in her obstetrical record during each clinic appointment throughout the pregnancy by the nursing staff. All women are weighed using the same electronic scale which is calibrated and validated by a medical engineering department according to the manufacturer's schedule. Total GWG was calculated by the difference between weight at 37 weeks of pregnancy and maternal weight measured at the first routine prenatal visit. The last weight considered for all mothers was assessed at 37 weeks' gestation because later in pregnancy, weight can be affected by swelling (54). The appropriate total GWG for a singleton, normal pregnancy was based on IOM recommendations (55). The Canadian GWG classification system depends on the mother's pre-pregnancy BMI. BMI was based on self-reported height and retrospective weight. The GWG recommendations for women who are underweight, normal weight, overweight, or obese are 12.5 to 18 kg, 11.5 to 16 kg, 7 to 11.5 kg and 5 to 9 kg, respectively (51).

GD was diagnosed according to guidelines from the Society of Obstetricians and Gynaecologists of Canada (SOGC) and the Canadian Diabetes Association (CDA) (14,15). In the absence of high-risk factors for GD (≥ 35 years of age, high risk ethnicity (Native American, African, Asian, Hispanic, South Asian), corticosteroid use, obesity, prediabetes, history of GD or macrosomia, parent with type 2 diabetes, polycystic ovary syndrome or acanthosis nigricans) all women are screened for GD between 24 and 28 weeks of pregnancy by measuring blood glucose one hour after ingestion of a 50 g glucose load. If the risk of GD is high, screening is performed during the first half of pregnancy and repeated between 24 and 28 weeks if the results were normal. A diagnosis of GD is made when plasma glucose is greater than 11.1 mmol/L. In women with a 1-hour plasma glucose between 7.8 and 11.0 mmol / L, a second induced hyperglycemia test with ingestion of 75 g of glucose is performed and leads to a diagnosis in cases in which the plasma glucose one hour after ingestion ≥ 10.6 mmol/L, or glucose two hours after ingestion ≥ 9.0 mmol/L, or if the fasting glucose ≥ 5.3 mmol/L.

Blood pressure is measured manually by nurses at each antenatal visit. GHT is defined by a blood pressure that first presents itself during the second half of pregnancy (≥ 20 weeks). The diagnosis of GHT is established by a systolic blood pressure ≥ 140 mmHg and/or a diastolic blood pressure ≥ 90 mmHg (21,56).

The weight of newborns is measured at birth without clothing using a standard electronic scale of the brand name "Medela Baby Weigh". The scale is calibrated and validated a minimum of once a year by a medical engineering service. Macrosomia was defined as a birth weight ≥ 4000 grams (28,1).

Data analysis

Sample size was determined based on the hypothesis that education from a nurse and PA prescription during pregnancy would be associated with a 10-point increase in the probability of having an optimal GWG according to the IOM recommendations. Because it is estimated that approximately 33% of Canadian women gain the IOM-recommended weight (6), it was estimated that 369 participants per group would provide a power of 80% with a 5% alpha error probability of noting an increase in the proportion of women who will gain the recommended weight if it reaches 43% in the group exposed to an enhanced care offer. Comparison between groups was assessed using t-tests for continuous variables and chi-squares for categorical variables. The dependent variables GD, GHT, and fetal macrosomia were treated as dichotomous (yes or no) categorical variables. The dependent variable GWG was treated as an ordinal variable with three modalities (low, normal, or high) (51). GWG, blood pressure, and newborn weight were also treated as continuous variables. For GWG and newborn birth weight, only children of women who carried the pregnancy to term were included in the analysis. Logistic regression models were used to compare the odds of GD, GHT, and fetal macrosomia among women in the two study groups. Similarly, polynomial logistic regression models were used to compare the odds of having any of the categories of GWG according to study group. Linear regression models were also used for GWG, blood pressure, and newborn weight, which were treated as continuous variables. Multivariate extensions of these regression models were used to adjust the results for potentially confounding variables (see tables for details). Other outcomes, such as GWG by pre-pregnancy BMI categories, type of delivery, induction of labor, perineal tears, episiotomy, prematurity, shoulder dystocia, and Apgar at one and five minutes of life were also compared between groups using t-test or Chi-square. Regression models for these variables were adjusted for BMI, age, and parity.

Results

Characteristics of participants

A total of 490 women who were followed at the obstetric clinic during the period of education delivery and PA prescription were invited to participate in the study following their delivery between November 2019 and September 2020. Of these, 465 (95%) consented to have their records and their babies' records accessed for this study, but 43 were excluded for a total of 422 (Figure 1). The GWG analyses were limited to the 394 women who delivered at term, the GD analyses included the 414 women who did not have other types of diabetes, the 411 women who did not already have high blood pressure were included in the GHT analysis, and all 422 newborns were included in the fetal macrosomia analyses.

For the comparison group, records of 475 women who delivered between January and September 2018 were assessed for eligibility. Of these, 81 women were excluded (Figure 1). Therefore, analyses were based on 394 mother-infant pairs. A total of 383 were included in the GWG analysis after exclusion of women with preterm delivery, 391 women had no other types of diabetes and were included in the GD analysis, the 389 women who did not already have high blood pressure were included in the GHT analysis. Because of one stillbirth at 18 weeks of pregnancy, 393 newborns were included for the macrosomia at birth analysis.

The group exposed to enhanced care and the group that received standard care did not differ with respect to women's mean age, mean pre-pregnancy weights, or pre-pregnancy BMI (Table 1). BMI categories, marital status, education level, maternal ethnic background, gestational age at first visit, primiparity, and history of GD, GHT, and depression or anxiety were also comparable between the two study groups.

Table 1 Baseline characteristics of study participants

	Intervention (n=422)	Comparison group (n=394)
Age (years)[a]	29.2 ± 5.3	29.3 ± 5.1
Height (cm)[a]	163.7 ±7.1	163.6 ± 7.0
Weight before pregnancy (kg)[a]	71.5 ± 17.9	72.2 ± 19.7
BMI (kg/m^2)[a]	26.7 ± 6.4	26.9 ± 7.0
BMI categories (n (%))		
< 18.5 kg/m^2	19/420 (4.5%)	14/393 (3.6%)
18.5-24.9 kg/m^2	187/420 (44.5%)	186/393 (47.3%)
25.0-29.9 kg/m^2	110/420 (26.2%)	94/393 (23.9%)
≥ 30 kg/m^2	104/420 (24.8%)	99/393 (25.2%)
Marital status (n (%))		
Single	36/407 (8.8%)	26/380 (6.8%)
Married	188/407 (46.2%)	199/380 (52.5%)
Common-law spouse	179/407 (44.0%)	153/380 (40.3%)
Education (n (%))		
Without a high school diploma	38/410 (9.3%)	27/390 (6.9%)
High school diploma	65/410 (15.9%)	59/390 (15.1%)
College diploma/trade school	142/410 (34.6%)	128/390 (32.8%)
University diploma	165/410 (40.2%)	176/390 (45.1%)
Ethnic or racial background (n (%))		
Caucasian	346/421 (82.2%)	340/392 (86.7%)
Other	75/421 (17.9%)	52/392 (13.3%)
Gestational age at first visit (week)[a]	11.1 ± 2.0	11.3 ± 1.68
First-born (n (%))	204/422 (48.5%)	204/394 (51.6%)
History of GD (n (%))	12/422 (2.8%)	9/394 (2.3%)
History of GHT (n (%))	12/421 (2.9%)	15/393 (3.8%)
History of depression/anxiety (n (%))	135/422(32.0%)	114/394(28.9%)

[a] mean ± standard deviation

Abbreviations: BMI Body mass index, GD Gestational diabetes, GHT Gestational hypertension.

Gestational weight gain

The odds of excess GWG were 29% lower in the group of women exposed to enhanced care compared with women who were followed during the standard care period (Table 2). The intervention was associated with a reduction in the proportion of women with excessive GWG in all pre-pregnancy BMI categories. Specifically, women who were exposed to the enhanced care and who started their pregnancies at normal weight, overweight, or obese had a greater likelihood of completing their pregnancies with a normal GWG, compared to women who received standard care. However, for women who were underweight at the beginning of their pregnancies, enhanced care was associated with a decreased likelihood of completing the pregnancy with a normal GWG as more of them ended with a low GWG. In sum, the average GWG was similar between women in the two groups.

Table 2 GWG in the intervention and comparison groups

	Intervention (n=422)	Comparison group (n=394)	p-value	unadjusted Odd ratio (95% CI)	adjusted Odd ratio (95% CI)
GWG					
Normal GWG	156/392 (39.8%)	124/382 (32.5%)	0,093	Reference	Reference
Low GWG	92/392 (23.5%)	95/382 (24.9%)		0.77 (0.53 - 1.15)	0.76 (0.52 - 1.10)
Excessive GWG	144/392 (36.7%)	163/382 (42.7%)		0.70 (0.51 - 0.97)	0.71 (0.51 - 0.99)
Normal GWG by BMI					
BMI < 18.5	6/17 (35.3%)	9/13 (69.2%)	0.100	0.15 (0.02 - 0.94)	0.17 (0.02 - 1.42)
BMI 18.5–24.9 kg/m^2	84/171 (49.1%)	72/185 (38.9%)	0.102	1.35 (0.83 - 2.20)	1.35 (0.83 - 2.22)
BMI 25.0–29.9 kg/m^2	36/103 (35.0%)	28/91 (30.8%)	0,629	0.92 (0.36 - 2.38)	0.84 (0.30 - 2.34)
BMI ≥ 30 kg/m^2	30/101 (29.7%)	15/93 (16.1%)	0,062	2.67 (1.12 - 6.37)	3.37 (1,31 - 8,67)
Excessive GWG by BMI					
BMI < 18.5	2/17 (11.8%)	2/13 (15.4%)	0.100	0.22 (0.02 - 2.67)	0.23 (0.01 - 5.63)
BMI 18.5–24.9 kg/m^2	36/171 (21.1%)	54/185 (29.2%)	0.102	0.77 (0.44 – 1.36)	0.78 (0.43 - 1.40)
BMI 25.0–29.9 kg/m^2	53/103 (51.5%)	53/91 (58.2%)	0,629	0.71 (0.29 - 1,75)	0.70 (0.27 - 1,85)
BMI ≥ 30 kg/m^2	53/101 (52.5%)	54/93 (58.1%)	0,062	1.31 (0.64 - 2,69)	1.68 (0.74 - 3,79)
	Intervention (n=422)	Comparison group (n=394)	p-value	unadjusted β (95% CI)	adjusted β (95% CI)
Total GWG (kg)[a]	12.2 ± 5.4 (n = 394)	12.4 ± 5.4 (n = 383)	0,642	0.02 (-0.58 - 0.95)	0.13 (-0.66 - 0.78)
Total GWG by BMI (kg)[a]					
BMI < 18.5 kg/m^2	12.1 ± 4.5 (n = 17)	14,5 ±3.4 (n = 13)	0,133	0.08 (-0.76 - 5.42)	0.21 (-1.02 - 5.35)
BMI 18.5–24.9 kg/m^2	13.5 ± 4.6 (n = 171)	13.8 ± 4.6 (n = 185)	0,646	0.01 (-0.74 - 1.19)	0.08 (-0.83 - 1.07)
BMI 25.0–29.9	12.2 ± 5.2 (n	12.8 ± 5.4 (n = 91)	0,447	0.03 (-0.92 - 2.07)	0.03 (-1.06 - 2.02)

kg/m^2	= 103)				
BMI ≥ 30 kg/m^2	10.1 ± 6.2 (n = 101)	9.1 ± 5.9 (n = 93)	0,262	0.07 (-2.71 - 0.74)	0.10 (-3.07 - 0.23)

[a] mean ± standard deviation

Abbreviations: BMI Body mass index, GWG Gestational weight gain

GWG is adjusted for GD, BMI, parity, age & education of the mother

The two study groups also differed significantly in their probability of developing GHT (Table 3). In the enhanced care group, 3.2% of women developed GHT compared to 11.8% of women who received standard care. The women who received the enhanced care therefore had 73% lower odds to develop GHT. The mean systolic and diastolic BP during pregnancy was higher in the women in the standard care group. However, there was no difference between the two study groups with respect to GD. The same was true for mean blood glucose one hour after ingestion of 50 grams of glucose, which did not differ between the two groups.

Among the other outcomes studied, the odds of labor induction or C-section due to pregnancy complications were 81% lower in the group that received enhanced care compared to the group that received standard care. Specifically, 1.2% of the women in the enhanced care group had an induction of labor and delivery due to GHT and/or preeclampsia compared to 6.4% of the women in the comparison group. There was also a difference between the groups in the odds of induction of labor and delivery for other reasons (oligohydramnios, post-term, etc.), but induction of labor and delivery due to GD or macrosomia did not differ between the groups. In addition, although the distribution of methods of delivery did not differ between the study groups, perineal tears and episiotomies were more common among women in the standard care group compared to women in the enhanced care group.

Table 3 Maternal and obstetrical outcomes

	Intervention (n=422)	Comparison group (n=394)	p-value	unadjusted Odd ratio (95% CI)	unadjusted Odd ratio (95% CI)
GD (n (%))	13/414 (3.1%)	15/391 (3.8%)	0.590	0.81 (0.38 - 1.73)	0.48(0.12 - 1.94)
Abnormal glycemia one h after ingestion of 50 g of glucose (mmol/L) (n (%))	53/408 (48.2%)	57/382 (51.8%)	0.433	1.16 (0.79 - 1.76)	1.77 (0.95 - 3.32)
GHT (n (%))	13/411 (3.2%)	46/389 (11.8%)	<0.001	0.24 (0.13 – 0.46)	0.27 (0.14 - 0.53)
Induction of labor GD (n (%)) GHT/preeclampsia n (%) Macrosomia (n (%)) Other (n (%))	 2/414 (0.5%) 5/411 (1.2%) 1/422 (0.2%) 15/422 (3.6%)	 7/391 (1.8%) 25/389 (6.4%) 2/394 (0.5%) 34/394 (8.6%)	 0.078 <0.001 0.523 0.002	 0.27 (0.06 -1.29) 0.18 (0.07 - 0.47) 0.48 (0.04 -5.42) 0.39 (0.21 - 0.73)	 0.31 (0.06 - 1.52) 0.18 (0.07 - 0.49) 0.49 (0.04 -5.42) 0.41 (0.22 - 0.77)
Induction of labor or C-section due to GD, GHT/preeclampsia, obesity, or macrosomia (n (%))	7/403 (1.7%)	35/387 (9.0%)	<0.001	0.18 (0.08 - 0.41)	0,19 (0.08 - 0.43)
Type of delivery Vaginal (n (%)) C-section (n (%))	 297/422 (70.4%) 125/422 (29.6%)	 277/393 (70.5%) 116/393 (29.6%)	 0.974	 1.01 (0.74 - 1.36)	 1.01 (0.74 - 1.38)
Perineal tears Perineum intact (n (%)) 1st degree (n (%)) 2nd degree (n (%)) 3rd degree (n (%)) Episiotomy (n (%))	 58/293 (19.8%) 86/293 (29.4%) 136/293 (46,4%) 13/293 (4.4%) 28/293 (9.6%)	 41/270 (15.2%) 66/270 (24.4%) 143/270 (53.0%) 19/270 (7.0%) 35/270 (13.0%)	 0.151 0.190 0.121 0.183 0.200	 1.38 (0.89 - 2.14) 1.28 (0.88-1.87) 0.76 (0.55 - 1.07) 1.61 (0.29 - 1.27) 0.70 (0.41 -1.20)	 1.42 (0.89 - 2.25) 1.28 (0.88 - 1.87) 0.77 (0.55 -1.07) 0.62 (0.30 - 1.29) 0.71 (0.42 – 1.20)
	Intervention (n=4222)	Comparison group (n=394)	p-value	unadjusted β (95% CI)	adjusted β (95% CI)
Glycemia one hr after ingestion of 50 g of glucose (mmol/L)[a]	5,9 ± 1,6 (n = 408)	6,2 ± 1,7 (n = 382)	0.125	0.03 (-0.05 - 0.41)	0.13 (0.41 - 0.64)
	108.3 ± 8.7	110.1 ± 9.6	0.005	0.01 (0.55 -	0.24 (0.61 -

Systolic BP (mmHg)[a]	(n=422)	(n=394)		3.07)	2.85)
Diastolic BP (mmHg)[a]	63.1 ± 5.5 (n=422)	63.9 ± 6.3 (n=394)	0.036	0.01 (0.06 - 1.67)	0.19 (0.04 - 1.50)

[a] mean ± standard deviation

Abbreviations : GHT Gestational hypertension, BP Blood pressure, GD Gestational diabetes

GD is adjusted for BMI, parity, history of GD and macrosomia, age & education of the mother

GHT is adjusted for GD, BMI, parity, history of GHT, age & education of the mother

Induction of labor, type of delivery and perineal tears adjusted for BMI, age, and parity

Neonatal outcomes

The average birth weight of newborns was significantly lower among newborns in the enhanced care group compared to those in the standard care group. Similarly, the odds of fetal macrosomia were 44% lower among newborns in the enhanced care group compared with newborns in the standard care group. However, there were no statistically significant differences between the two study groups regarding premature birth, shoulder dystocia, and Apgar score at one and five minutes of life.

Table 4 Neonatal outcomes in the study groups.

	Intervention (n=422)	Comparison group (n=393)	p-value	unadjusted Odd ratio (95% CI)	unadjusted Odd ratio (95% CI)
Sex Female (n (%)) Male (n (%))	215/421 (51.1%) 206/421 (48.9%)	186/389 (47.8%) 203/389 (52.2%)	0.355	0.87 (0.66 - 1,15)	0.89 (0.67 - 1.17)
Macrosomia (n (%))	30/396 (7.6%)	46/380 (12.1%)	0.034	0.60 (0.37- 0.97)	0.56 (0.34 - 0.93)
Premature birth (n (%))	26/422 (6.2%)	14/393 (3.6%)	0.085	1.78 (0.92 - 3.47)	1.81 (0.93 - 3.53)
Shoulder dystocia (n (%))	26/293 (8.9%)	34/270 (12.6%)	0.153	0.68 (0.40 -1.16)	0.65 (0.38 - 1.12)
	Intervention (n=422)	Comparison group (n=393)	p-value	unadjusted β (95% CI)	unadjusted β (95% CI)
Weight at birth (g)	3400.0 ± 450.8 (n =396)	3470.1 ± 445.8 (n =380)	0.030	0.01 (6.85-133.25	0.17 (14.05 - 132.43)
Apgar score at 1 min (n (%))	8.6 ± 1.3 (n =422)	8.4 ± 1.5 (n =392)	0.196	0.02 (-0.32-0.06)	0.02 (-0.30-0.08)
Apgar score at 5 min (n (%))	8.9 ± 0.5 (n =422)	8.8 ± 0.7 (n =392)	0.112	0.03(-0.16-0.02)	0.01 (-0.15-0.02)

[a] mean ± standard deviation

Birth weight and macrosomia are adjusted for parity, age & education of the mother, and interaction between GD, BMI, and GWG.

Discussion

These results suggest that a simple intervention combining education from a nurse and prescription of PA from a physician during pregnancy follow-up may be an effective tool for preventing excessive GWG, decreasing the risk of GHT, preventing the onset of labor and delivery due to GHT and/or preeclampsia, and reducing the risk of fetal macrosomia.

In the present study, a combination of education and PA prescription was associated with a six-percentage point decrease in the proportion of women exceeding the recommended GWG. Previous studies that had investigated the effects of personalized GWG education (57) or a combination of personalized GWG education and PA prescription in maternal care (7) had not found significant effects. It is possible that our study differs from others by having adopted a mode of operation that was designed to be easily integrated in the setting and practices of an obstetric clinic without requiring additional resources or considerable time. In addition, the combination of actions by a nurse and a physician may also have contributed to the success of the intervention. A review of systematic reviews and meta-analyses showed that physician advice is effective in increasing PA in the short term (34). However, PA prescriptions are rarely used as physicians identify time constraints as a barrier to their implementation (58,59). In the current study, nurses provided education on PA and assessed women's intention to change their PA level, which allowed physicians to rapidly complete their PA prescriptions. Physician interventions are thought to be effective because they are perceived by the population as the most credible source of health information (60,39). In addition, PA prescriptions provide a concrete reinforcement of the importance of the recommended action (39,41, 61). Similarly, it is possible that women became more sensitised to the importance of PA as they noted the complementary actions of two health professionals. Empirical evidence supports this as it is commonly reported that interprofessional collaborations lead to more effective care and provides better clinical health outcomes for patients (62,63). In particular, a systematic review of randomized trials showed that collaborations between nurses and physicians have a positive effect on patient health (62). This is also consistent with findings indicating that one-on-one PA education offered by nurses and reinforced by physicians to pregnant women encourages greater adherence to PA recommendations (64).

Our results coincide with the results of randomized trials of lifestyle interventions during pregnancy which led to lower GWG (65). However, our intervention is the only one to demonstrate a significant decline in the prevalence of GHT and mean systolic and diastolic BP (54,57,66). Our results also differ from a few studies that did not lead to a significant reduction in newborn birth weight or macrosomia (7,54,67-69), but still similar to one where a lifestyle intervention was associated with lower newborn weight (57). As had been suggested in previous studies, it is possible that the higher prevalence of excessive GWG in our standard care group is directly related to the higher risk of macrosomia for this group (29,70). It is also relevant to mention that although the intervention did not aim to improve all maternal and fetal outcomes such as type of delivery, perineal tears, episiotomy, prematurity, shoulder dystocia, and Apgar score at 1 and 5 min, improvements in several outcomes were noted.

Beyond the practicability of the intervention, the power of prescriptions and the advantages of interprofessional collaborations, it is possible that gains in GWG awareness through a personalized weight gain chart positively influenced outcomes in the intervention group. It was previously shown that pregnant women who follow WG based on pre-pregnancy BMI are three times more likely to achieve recommended pregnancy weights (71). It is also conceivable that tailoring PA prescriptions based on behavioral stages of change has had the beneficial effect of improving some maternal and fetal outcomes. Systematic reviews (45,72) demonstrate that stages of behavior change are directly related to PA in adults (45) and other reviews document that interventions based on this model are generally effective in changing PA behavior (46-48,72,73).

Despite all the positive effects of the intervention tested in the present study, it was not associated with a lower prevalence of GD. Lifestyle interventions have had mixed results on GD with some showing no effects (57,66,68) and others being associated with a reduction in GD (54,74). In general, interventions that succeed in preventing GD focused on diet (14,54,74). Our study did not focus on diet given that the obstetric clinic where the study took place already provided detailed education about diet during pregnancy. Thus, it is possible that the potential for further improvement was reduced given that the clinic's standard of care already included an intervention targeting one of the key predictors of GD.

This study has several strengths. Only 5% of women followed up during the intervention period refused to give consent to access their records and those of their baby's, which eliminates the risk of selection bias and makes the results generalizable to other settings. The generalizability of the results is also supported by the fact that the sample of the comparison and experimental groups are similar and are also comparable to the general population. However, this study has some limitations. Randomized control trials represent the gold standard design for assessing the effectiveness of interventions (75,76). This design was not used in the principle of fairness to allow all women to benefit from the preventive intervention that was previously estimated to be favorable for their health (77). Nevertheless, the design used adapts well to the constraints of natural environments and represents a valuable contribution to clinical research since there is no reason to believe that factors other than the intervention may have had a significant influence in differentiating the two time periods under study (75). However, the participants were from a single hospital, which may reduce the generalizability of the results to other settings. Data collected on pre-pregnancy weight were self-reported, which may reduce the accuracy of this information. For this variable, most studies have noted a slight underestimation of self-reported values. However, because both groups are subject to this same underestimation, the possibility of social desirability bias should not impact the overall findings (78). GWG was calculated as the difference between the last pregnancy weight and the maternal weight measured at the first prenatal visit. It is possible that the GWG was underestimated by not considering the WG in the early weeks of pregnancy. However, the literature suggests that this limitation is minimal since the majority of GWG occurs in the 2nd or 3rd trimester of pregnancy (55). To ensure fidelity of intervention implementation throughout the duration of the study, intervention evaluation tools were used, numerous follow-ups were conducted with the care team, and training was provided. Despite these control measures, it is not possible to control whether the intervention was consistently delivered as planned.

Conclusion

This study suggests that using a combination of nurse education and physician prescription of PA according to the transtheoretical model in a routine prenatal care setting is effective in improving several maternal and fetal outcomes. The intervention appears to be particularly effective in reducing the risk of excessive GWG, GHT, fetal macrosomia, induction of labor, or having a C-section because of obesity, GHT, GD, and macrosomia.

Abbreviations

BMI Body mass index

BP Blood pressure

CI Confidence interval

DGLDUHC Dr. Georges-L.-Dumont University Hospital Centre

GD Gestational diabetes

GHT Gestational hypertension

GWG Gestational weight gain

IOM Institute of Medicine

OR Odds ratio

PA Physical activity

SD Standard deviation

WG Weight gain

Declarations

- Ethics approval and consent to participate

The project was approved by the Research Ethics Committee of the Vitalité Health Network on March 7, 2019, and renewed annually thereafter. The project also received approval from the Ethics Committee for Research on Human Beings from the Faculty of Graduate Studies and Research of l'Université de Moncton on April 5, 2019 (#1819-054). This same committee renewed its approval on March 5, 2020.

- Consent for publication

Not applicable

- Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author [L. S.]. The data are not publicly available due to "them containing information that could compromise research participant privacy/consent".

- Competing interests

The authors declare that they have no competing interests

- Funding

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- Authors' contributions

LS, MB, and PG all participated in the development of the protocol for this research. LS led the data collection, statistical analysis and writing of the manuscript. CMC help with bibliographic work and revision of the manuscript. LS, MB and PG contributed significantly to the scientific content of the manuscript, the writing of the manuscript, and the interpretation of the data. All authors approved the final version of the manuscript.

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Figures

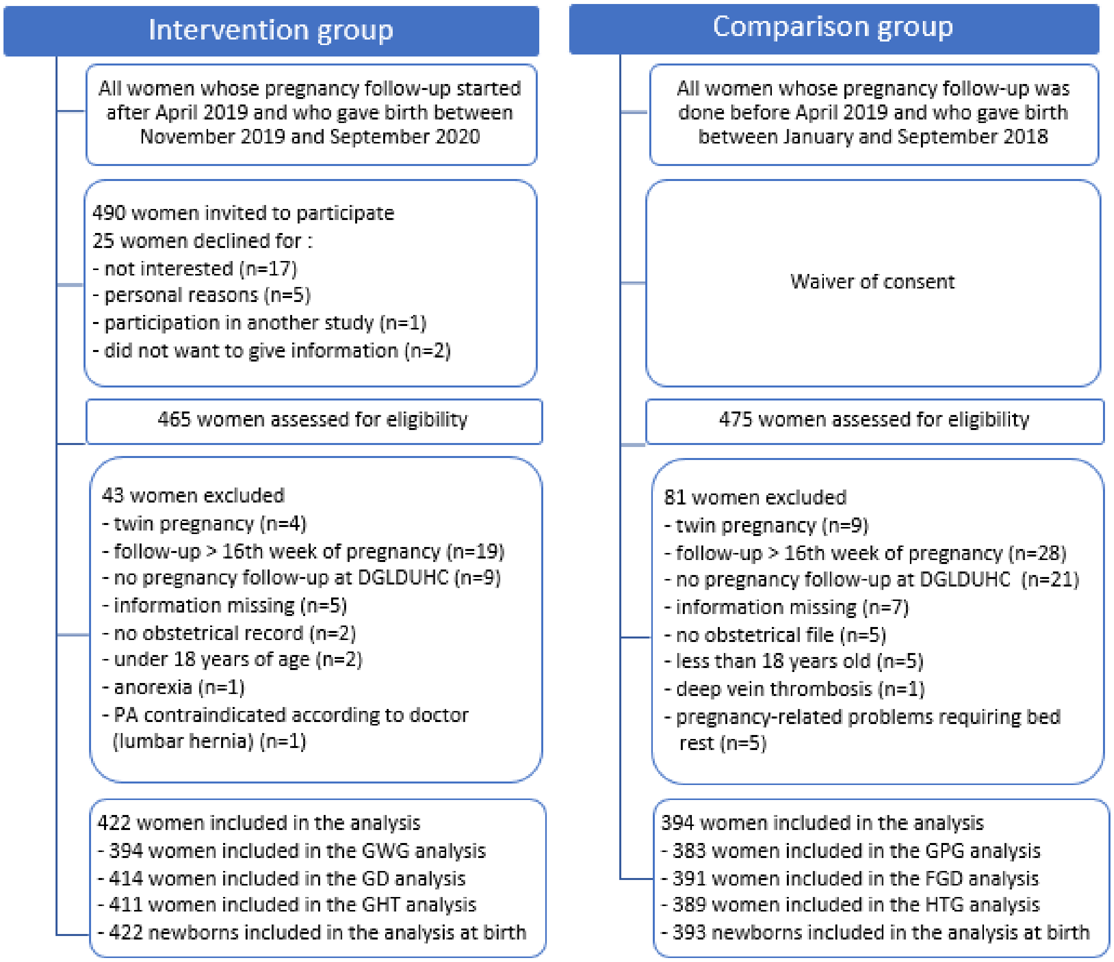

Figure 1

Flow chart of study participants

Abbreviations: DGLDUHC Dr. Georges-L.-Dumont University Hospital Centre, PA Physical activity, GWG Gestational weight gain, GD Gestational diabetes, GHT Gestational hypertension.