International Journal of Behavioral Medicine (2020) 27:108–118
https://doi.org/10.1007/s12529-019-09840-0

FULL LENGTH MANUSCRIPT

Sequential Introduction of Exercise First Followed by Nutrition Improves Program Adherence During Pregnancy: a Randomized Controlled Trial

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Published online: 23 December 2019

Abstract

Background Adhering to nutrition and exercise recommendations simultaneously during pregnancy may be challenging. The purpose was to examine adherence to the sequential introduction of nutrition and exercise behaviors during pregnancy in comparison with a simultaneous approach.

Method A randomized controlled trial including nutrition and exercise was executed. Using a stratified body mass index (BMI) randomization, participants ($n = 88$) were allocated to one of three groups at 12–18 weeks gestation. Group A received nutrition and exercise simultaneously. Group B received nutrition first and Group C received exercise first, and the second behavior was added at 25 weeks gestation for both groups. The program included weekly weighing, supervised walking sessions, and/or nutrition counseling. Adherence (primary outcome) was measured by scoring women on meeting the intervention goals (3 nutrition and 3 exercise goals) and converted to a percentage. Secondary health outcomes were gestational weight gain (GWG) and excessive GWG on the program, birthweight, macrosomia (birthweight > 4000 g), and low birthweight (birthweight < 2500 g).

Results Group C ($n = 23$) had the highest adherence to the program (80.2 ± 14.7%) compared with Groups A ($n = 17$; 60.9 ± 17.9%) and B ($n = 20$; 66.8 ± 16.7%; $p < 0.05$, $\eta_p^2 = 0.26$). There was a significant effect for gestational weight gain ($p < 0.05$; $\eta_p^2 = 0.10$) as Group C gained less weight (7.7 ± 2.2 kg) over Group B (9.8 ± 2.8 kg; $p = 0.04$), however, not Group A (9.1 ± 3.5, $p = 0.35$). Non-significant small effects favored Group C for the prevention of EGWG (Cramer's $V = 0.13$).

Conclusion Introducing exercise first followed by nutrition at 25 weeks gestation can improve adherence to multiple behavior change programs and thus have a positive effect on health outcomes.

Trial Registration ClinicalTrials.gov Identifier: NCT02804061

Keywords Pregnancy · Adherence · Nutrition · Exercise · Behavior change · Gestational weight gain

Introduction

Excessive gestational weight gain (EGWG) significantly increases the risk for pregnancy complications that may impact both the mother and baby, including later life obesity [1–3]. Women who gain weight excessively during pregnancy are at an increased risk for delivering babies with a birthweight > 4000 g (macrosomia) and < 2500 g (low birthweight, LBW),

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which are both positively correlated with childhood and adult obesity [4, 5]. In North America, more than 50% of women gain excessively during pregnancy [6]. The Institute of Medicine (IOM) defines EGWG as gaining above 16.0 kg, 11.5 kg, and 9.0 kg for women with a pre-pregnancy body mass index (BMI) in normal weight (≥ 18.0–24.9 kg/m^2), overweight (≥ 25.0–29.9 kg/m^2), and obese (≥ 30.0 kg/m^2) categories respectively [7].

Excessive gestational weight gain is a modifiable risk factor for pregnancy complications and may be prevented by providing women a lifestyle intervention that includes both nutrition and exercise [8, 9]. However, results of individual studies have been inconsistent, with some studies successfully achieving statistical significance favoring the intervention group while others having a null effect [10, 11]. A common limitation mentioned in many lifestyle interventions is low program adherence [12–15]. Adherence is defined as the degree to which individuals follow recommendations of healthcare providers, including lifestyle behavior change goals [16]. Previous lifestyle interventions have measured adherence in a variety of ways, most commonly including attendance and use of self-monitoring methods such as pedometers or food diaries [16]. Overall, the method used to measure and report adherence is often selected based on the study design and what would best indicate participant engagement with the intervention recommendations [16]. It has been suggested that lifestyle interventions with low adherence are more likely to have a limited effect on the primary health outcome being investigated, as both the intervention and control groups may be performing similarly [16].

One potential strategy that may increase adherence to lifestyle interventions during pregnancy is the introduction of nutrition and exercise behavior changes sequentially rather than simultaneously. Sequential introduction may allow a period of time to master one set of behavior change goals before adding the second [17, 18]. Adherence to nutrition and exercise constitutes prime examples of behaviors that require the exertion of self-control (i.e., ability to abstain from gratifying immediate needs and desires, inhibiting strong impulses) and self-regulation (reducing the frequency and intensity of strong impulses) [19]. Researchers have identified lapses in self-regulation as a key mediator of lifestyle change interventions [20]. The ability to exert control over oneself (i.e., self-regulate) has been shown to delay gratification from immediate unhealthy needs and desires and engage in goal-directed behavior to instigate long-term positive outcomes [21, 22]. Research into self-regulation and failure to control strong impulses has often adopted social cognitive models in which self-regulation is viewed as a function of expectations, attitudes, efficacious beliefs, and intentions [23–25]. It is reasonable to assume that changing multiple behaviors together (nutrition and exercise) is likely to tax self-control resources and lead to self-regulatory failure more so than changing sequential single behaviors (nutrition or exercise) [19].

Authors investigating non-pregnant adults reported that sequential and simultaneous approaches of introducing behaviors improved health outcomes equally compared to a standard care control group [18, 26]. It is important to note however that these studies have only evaluated adherence as retention (drop-out rate), with no differences found between the simultaneous and sequential approaches [18, 26]. Furthermore, previous research in non-pregnant populations has also suggested that there may be a spill-over or gateway effect of introducing and successfully changing one health behavior at a time [27, 28]. Successfully changing one behavior may increase the motivation to then improve additional lifestyle behaviors. Evidence from the non-pregnant literature shows that exercise may be a gateway to nutrition behavior change. For example, one study among older adults found that participants who reported meeting exercise goals also showed an improvement in nutrition intake [27]. Similarly, an exercise intervention among non-pregnant women reported that women who met recommended exercise goals also increased their fruit and vegetable intake [28]. This suggests that there may be an optimal sequence to introducing multiple behavior changes (i.e., nutrition before exercise or exercise before nutrition). Lifestyle behavior change interventions during pregnancy have tested other strategies to improve adherence, including the use of self-monitoring resources and delivery of interventions in group settings [8, 10, 11]. Previous studies have measured adherence to nutrition and exercise behaviors separately or as one intervention together [10–15]; however, no study to date has compared adherence with both approaches within the same intervention. The simultaneous versus sequential approach of behavior change requires further investigation in terms of program adherence and to date has not been assessed among pregnant women for nutrition and exercise behavior change.

As both nutrition and exercise have health benefits during pregnancy, the purpose of the current study was to determine whether there is greater adherence (primary outcome) to the goals of a lifestyle intervention (nutrition and exercise) if the introduction of behaviors are sequential rather than simultaneous. Secondary outcomes included examining health outcomes of interest and determining if the group with the highest adherence also reported lower gestational weight gain and excessive weight gain on the program, birthweight, and prevalence of macrosomia and LBW. It was hypothesized that greater adherence will be found with the sequential introduction of nutrition or exercise compared with presenting both behaviors simultaneously. Additionally, based on findings among non-pregnant studies, higher adherence will be found in the group where exercise is introduced first compared with first introducing nutrition behavior change.

Methods

The current study was part of a larger stratified randomized controlled trial (RCT; ClinicalTrials.gov identifier: NCT02804061) including three strategies and was completed and reported following CONSORT guidelines for an RCT [29]. The research protocol was reviewed and approved by the Western University Human Research Ethics Board. Healthy pregnant women between 12 and 18 weeks gestation were recruited to participate through social media, community advertisements, and posters in physician and midwifery clinics in London, Ontario, Canada. All women provided written informed consent. Before beginning the program, women were medically prescreened using the PARMed-X for pregnancy [30] to assure that they were able to participate in a physical activity intervention. Women were excluded if they had any contraindications for exercise during pregnancy [31], were > 18 weeks gestation, ≤ 18 years of age, were not pregnant with a singleton, had diabetes during or before pregnancy, smoked during pregnancy, were exceeding physical activity guidelines during pregnancy as indicated on the PARMed-X for pregnancy [30, 31], or had any other chronic condition. Study participants and investigators were not blinded to group assignment. Individual checking data were blinded to group.

Intervention Strategies

The current RCT had three intervention arms and was based on a simultaneous approach previously examined in our lab (Nutrition and Exercise Lifestyle Intervention Program, NELIP) [32, 33]. The NELIP includes both a nutrition and exercise component and has been successful in preventing EGWG among women with a normal weight [32] and overweight [33] pre-pregnancy BMI when participants had high adherence to the program [34]. Therefore, the current study tested three strategies (Fig. 1) including nutrition and exercise components introduced together (simultaneous introduction; Group A), nutrition first followed by exercise added at 25 weeks gestation (sequential introduction; Group B) and exercise first followed by nutrition added at 25 weeks gestation (sequential introduction; Group C) to examine the effect of these strategies on program adherence. Adherence to the program was measured until 36 weeks gestation (final assessment); however, all women were encouraged to follow nutrition and exercise goals until delivery.

Nutrition Component The meal plan was a modified gestational diabetic diet that was designed to prevent gestational diabetes and allow for appropriate gestational weight gain [33]. The meal plan included aiming for a total energy intake of approximately 1800–2200 kcal/day, complex carbohydrates with an overall goal of 200–250 g/day, and eating three balanced meals with 3–4 snacks per day [33]. The nutrition program was explained to women in person and they were given a written document to take home. Participants submitted a one-day food intake record and met with study investigators once a week. During their weekly face-to-face visit, participants were weighed and were provided individualized nutrition counseling including ideas for snacks, discussions on how to improve meals, and opportunities for asking additional questions. Food records were analyzed using Nutritionist Pro™. To track their food intake, women were given the options of using paper food logs, email logs, or an application of their choice.

Exercise Component The exercise component was a self-paced mild-intensity walking program. All walks were planned, structured, and intentional sessions. Participants submitted a weekly home exercise log and met with study investigators once a week. During their weekly face-to-face visit, participants were weighed and had a supervised walking session with the study investigator. Walks began at 25 min with 2 min added each week until a walk of 40 min was achieved and maintained until the end of the intervention. Additionally, women were asked to walk at least two more times on their own for a total of at least three walking sessions per week [33]. The exercise goals were outlined for women in person and they were given a written document to take home. To monitor the intensity of the walks, the "talk test" (can maintain a conversation while exercising, can converse but not sing) was used as it is a non-intrusive and is an easily accessible option that women could follow on their own, without the need of additional equipment [35]. According to the 2019 Physical Activity Guidelines throughout Pregnancy, pregnant women without any contraindications can engage in mild intensity exercise, such as walking [31]. Benefits of exercise are attained from a mild intensity, and women are recommended to start low and build their intensity according to their level of comfort [31, 33, 36]. A mild intensity was selected to assure all women could safely participate both in a supervised setting and on their own, and still gain health benefits from a walking program [33, 35, 36]. To track additional walking sessions outside of the laboratory setting, women were given the option of submitting a weekly paper exercise log, email log, or using another application of their choice to self-monitor their behavior.

All three intervention arms were delivered by the same investigator (TSN) who was trained (one full day of training) by the original NELIP investigator (MFM) to provide both the nutrition and exercise components in accordance with the previous protocol [32, 33]. Training for the nutrition component included reviewing the modified gestational diabetic diet and general tips that can be provided (previously published, 32), learning how to enter and analyze data from Nutritionist Pro™, and reviewing how to explain the level of detail

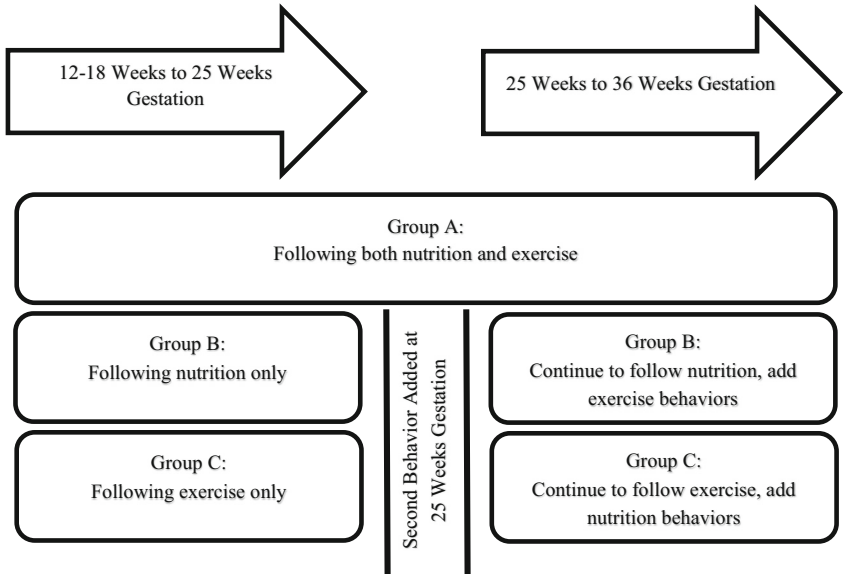


Fig. 1 Diagram describing three strategies for timing of introducing the nutrition and exercise components of multiple behaviors during pregnancy

required for food intake records (e.g., include everything you ate and drank that day, include condiments, if available provide the brand of a product, provide serving sizes that could be exact measurements, or use objects to describe this such as hand measurements, be as specific as possible). Training for the exercise session included practicing how to describe self-measurement of exercise intensity (talk test), reviewing how to log at-home exercise sessions (provide the length of your walk, how often did you go), and discussing how to present tips and suggestions to achieve exercise goals.

Measurements

Demographic Characteristics At baseline (12–18 weeks gestation), women completed a weight and health history questionnaire [37]. This questionnaire included the following information: age, parity, education, ethnicity, and weight immediately before the current pregnancy. Women completed this questionnaire at their first visit to the lab, and an investigator (TSN) was present to answer any questions. Height was measured using a standard stadiometer.

Program Adherence (Primary Outcome) Adherence was measured on a weekly basis by scoring the participants on meetings the goals of the nutrition and/or exercise program using a previously developed system [34]. There were six goals in total, three goals for nutrition and three for exercise (total adherence score out of 6). All participants had the same nutrition and/or exercise goals to meet. The adherence goals and measurement are described in Table 1. For the two sequential groups, until the second intervention was added, they were scored out of three (three goals for nutrition or exercise) on a weekly basis. All adherence scores were converted to a percentage. Average adherence was calculated for each participant for the full program, from the beginning of the intervention until 25 weeks gestation and from 25 weeks gestation (second behavior was added for the two sequential groups at this time) until 36 weeks gestation (Fig. 1). Additionally, we considered attrition (drop-out rate) as a secondary measure of adherence to the intervention strategies in order to determine if perhaps one method of introducing the nutrition and exercise interventions resulted in an increased likelihood of completing the program. The same investigator measured adherence on a weekly basis (TSN).

Exit Survey An exit survey was completed at the end of the intervention to further inform program adherence by evaluating preference of the sequential or simultaneous introduction of interventions and difficulty of the nutrition and exercise goals. This survey asked participants to rank the difficulty level of the nutrition and exercise goals on a Likert scale (1 = Very Difficult; 2 = Difficult; 3 = Neutral; 4 = Easy; 5 = Very Easy). Additionally, participants were asked to indicate if they preferred the group they were assigned or not. Surveys were completed by the participant, with the investigator present to answer any questions.

Secondary Health Outcomes (Gestational Weight gain and EGWG on the Program, Birthweight, Macrosomia, and LBW) Using self-reported pre-pregnancy weight and measured height, pre-pregnancy BMI was calculated. Gestational weight gain on the program was measured by subtracting weight at program entry from final visit weight on the program (36 weeks gestation). Excessive gestational weight gain was defined using the 2009 Institute of Medicine guidelines [7]. Regardless of pre-pregnancy BMI, women were expected to

Table 1 Weekly adherence scoring based on the goals of the nutrition and exercise components of the three strategies

Weekly program goals				Total
Nutrition goals	Submit a weekly food intake record (0.5 point); attend face-to-face nutrition counseling session (0.5 point)	Average daily energy intake of 1800–2200 kcals (0.5 point); three balanced meals and 3–4 snacks per day (0.5 point)	Average daily carbohydrate intake of 200–250 g (1 point)	Total: 3 (%) points per week
Exercise goals	Submit a weekly exercise record (0.5 point); attend face-to-face supervised walking session (0.5 point)	Complete one additional walk on their own that week for the allocated time (1 point)	Complete a second additional walk on their own that week for the allocated time (1 point)	Total: 3 (%) points per week
				Total adherence: 6 goals = 6 points per week (%)

Adherence for Groups B (nutrition introduced at 12–18 weeks followed by sequential introduction of exercise at 25 weeks gestation) and C (exercise introduced at 12–18 weeks followed by sequential introduction of nutrition at 25 weeks gestation) was scored as a percentage of 3 until 25 weeks gestation (when the second behavior was added). Adherence for Group A (both nutrition and exercise introduced at study entry and followed until the end of the program) was scored as a percentage of 6 throughout the intervention. All scores were converted to a percent value

gain 2.0 kg in the first trimester [7]. Following this, weekly gestational weight gain is recommended to be no more than 0.50 kg, 0.33 kg, and 0.27 kg for women with a normal weight, overweight, and obese pre-pregnancy BMI, respectively [7]. Therefore, EGWG on the program was individually determined as gaining above the following equation: expected rate of weight gain according to pre-pregnancy BMI (kg) × number of weeks on the program. Birthweight was retrieved from an in-hospital visit within 6 to 18 h after delivery. Macrosomia and LBW were defined as birthweight > 4000 g and < 2500 g, respectively.

Sample Size Calculation

To our knowledge, this is the first pregnancy RCT where the primary outcome of interest is program adherence for a nutrition and exercise intervention during pregnancy, and an a priori sample size calculation was not completed. A post hoc power analysis was completed for all outcomes and observed power and effect sizes are reported.

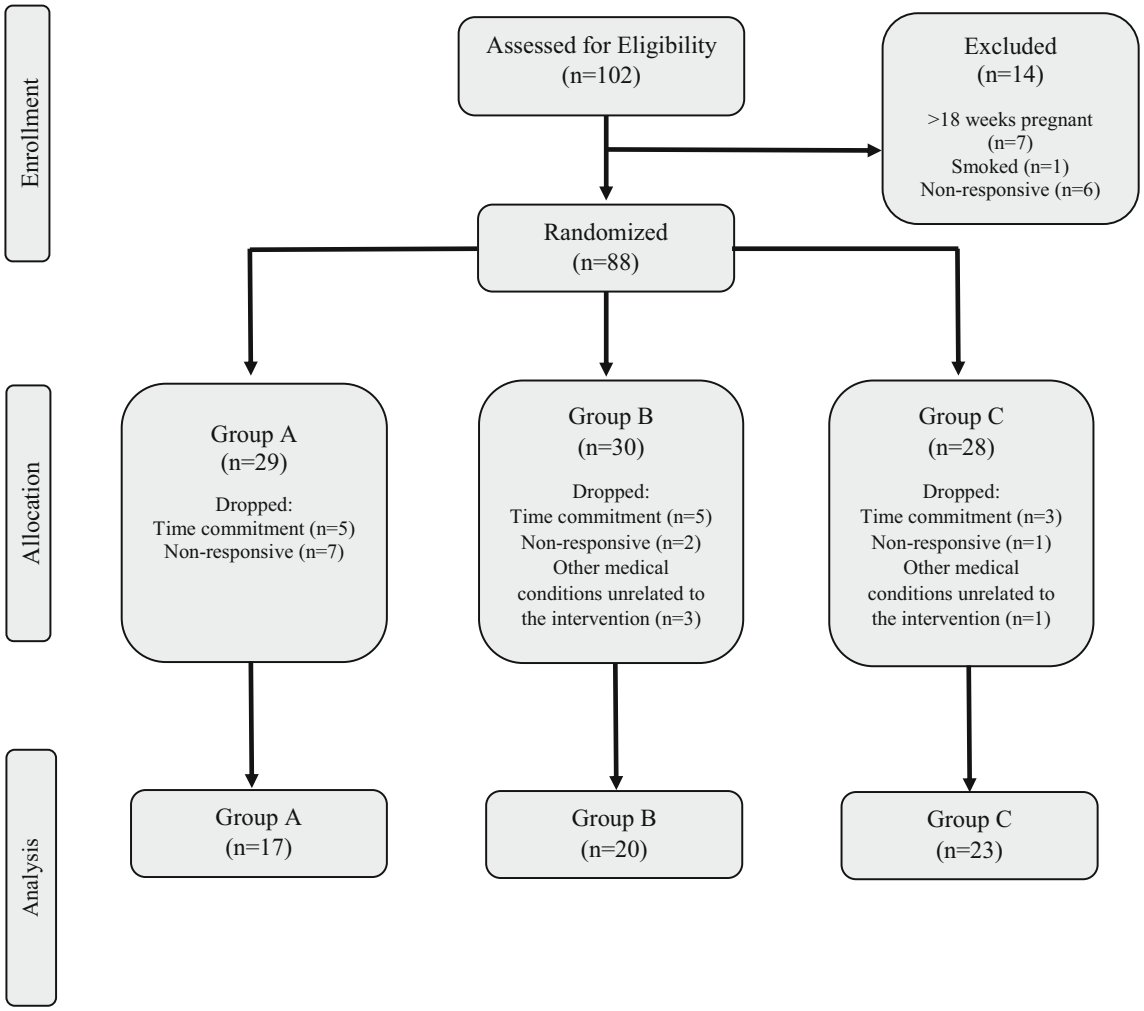
Randomization

Stratified randomization was conducted, controlling for pre-pregnancy BMI categories (normal weight, overweight, and obese). Randomization occurred in blocks of three (Groups A, B, and C) for each pre-pregnancy BMI group. An independent person not involved with administering or assessing the intervention assigned participants to each group using sequentially numbered concealed opaque envelopes. The same study investigator informed all participants of group assignment and explained the specific goals as mentioned above.

Statistical Analysis

An intent to treat approach was not followed in the current study for the following reasons. First, for participants who completed the program, there was no item-level response missing data for program adherence (primary outcome) as they were followed and scored on a weekly basis. Therefore, using recommended intent to treat analysis approaches to handle missing data (i.e., multiple imputation) was not necessary [38]. Furthermore, we might expect differential loss (retention) across treatment conditions, which is another form of adherence. Imputation of unit-level response missing data that are not at random requires strong assumptions that may be hard to justify [39]. Birthweight and exit survey data were not available for three women, representing less than 10% of the data. It has been recommended that imputation of missing data this low is not required [40]. For these reasons, all subsequent analyses included observed data only.

One-way ANOVA and Student's *T* test were performed to compare percent mean adherence to the full program and to nutrition and exercise goals individually (overall program adherence; adherence from beginning of the program to 25 weeks gestation; adherence from 25 weeks to 36 weeks gestation). One-way ANOVA was performed to compare gestational weight gain on the program and birthweight between the three groups. Chi square analysis was performed to compare the number of women who gained excessively while on the program, prevalence of macrosomia, and LBW between groups. One-way ANOVA was performed to compare demographic characteristics between groups, including maternal age, parity, and pre-pregnancy BMI. Other demographic characteristics compared between groups including education and



Group A: Both nutrition and exercise delivered simultaneously
Group B: Nutrition introduced first followed by exercise added at 25 weeks gestation
Group C: Exercise introduced first followed by nutrition added at 25 weeks gestation

All women followed both behavior changes until the end of the program.
Non-responsive means that the participant did not attend scheduled visit and could not be contacted further

Fig. 2 CONSORT flow diagram of three study groups

ethnicity were assessed using chi square analysis. Exit survey responses for each group were compared using both one-way ANOVA and chi square analysis. Effect sizes were calculated following Cohen's (1988, 1992) criteria [41, 42]: Cohen's *d* for Student's *T* test: small = 0.20, medium = 0.50, large = 0.80; Cramer's *V* for chi square analysis: small = 0.10, medium = 0.30, large = 0.50; and partial eta squared for one-way ANOVA: small = 0.01, medium = 0.06, large = 0.14. Additionally, 95% confidence intervals and power were reported for all analyses. All statistical analyses were performed in SPSS Version 23.

Results

Recruitment

Participants were recruited from August 2016 to August 2018. One hundred and two pregnant women were assessed for eligibility of which 88 met the criteria and were randomized. Women who completed the study were included in the final analysis: 17 women in Group A, 20 women in Group B, and 23 women in Group C. A participant flow diagram, including reasons for drop-out, is presented in Fig. 2.

Table 2 Demographic characteristics of all participants in each strategy. All data are presented as mean ± sd unless otherwise indicated

	Group A (simultaneous) $n = 17$	Group B (nutrition first) $n = 20$	Group C (exercise first) $n = 23$
Age (years)	32.6 ± 4.3	31.7 ± 3.1	32.3 ± 3.3
Parity	0.4 ± 0.7	0.3 ± 0.6	0.3 ± 0.8
Pre-pregnancy BMI (kg/m^2)	27.0 ± 3.5	25.3 ± 5.3	26.7 ± 5.8
Pre-pregnancy BMI category (n; %)			
Normal weight	6; 35	11; 55	12; 53
Overweight	8; 47	6; 30	7; 30
Obese	3; 18	3; 15	4; 17
Ethnicity (n; %)			
Caucasian	15; 88	20; 100	21; 91
Asian	1; 6	0; 0	1; 4.5
Hispanic	1; 6	0; 0	0; 0
African American	0; 0	0; 0	1; 4.5
Education (n; %)			
College	2; 12	3; 15	1; 4.5
Bachelors	5; 29	7; 35	13; 57
Masters	9; 53	7; 35	7; 30
Doctorate	1; 6	3; 15	2; 8.5
Gestational age at program entry (weeks)	16.1 ± 2.3	16.4 ± 2.3	15.7 ± 2.5

Group A both nutrition and exercise introduced simultaneously; Group B nutrition introduced first followed by sequential introduction of exercise at 25 weeks gestation; Group C exercise introduced first followed by sequential introduction of nutrition at 25 weeks gestation. All women followed both behavior changes until the end of the program. *BMI* body mass index

Demographics

There were no differences between the three groups for demographic characteristics including pre-pregnancy BMI, age, education, ethnicity, and parity. Demographic characteristics are presented in Table 2. There were no significant differences in demographic data between the women who dropped out of the interventions and those who completed the program and were included in the analysis.

Adherence Scores and Retention (Drop-out)

Average total adherence to the full program was statistically different (F (2, 57) = 7.51, $p = 0.001$, $\eta_p^2 = 0.21$, observed power = 0.93) as adherence to Group C (80.2 ± 14.7%) was significantly higher than adherence in both Groups A (60.9 ± 17.9%, $p = 0.001$) and B (66.8 ± 16.7%; $p = 0.028$). Average adherence was statistically different from 25 weeks until 36 weeks gestation (F (2, 57) = 6.06, $p = 0.004$, $\eta_p^2 = 0.18$, observed power = 0.87) as Group C had higher adherence (74.3 ± 17.9%) than Group A (53.2 ± 21.8%, $p = 0.03$). For nutrition goals only, there were no statistical differences found between Groups A and B from the beginning of the program to 25 weeks gestation (t (35) = − 0.81, $p = 0.42$, Cohen's d = 0.02). From 25 weeks to 36 weeks, there was a statistical difference for adherence to nutrition only (F (2, 57) = 3.74, $p = 0.03$, $\eta_p^2 = 0.12$, observed power = 0.66), with higher adherence to the nutrition goals in Group C (75.1 ± 22.3%) than Group A (56.6 ± 21.4%, $p = 0.03$), however, not Group B (66.7 ± 19.1%, $p = 0.60$). Although trending towards significance, adherence to exercise goals only was not statistically different between Groups A (76.1 ± 18.2%) and C (86.1 ± 15.0%) from the beginning of the program to 25 weeks gestation (t (38) = − 1.91, $p = 0.06$, Cohen's $d = 0.09$). There was no statistical difference for adherence to the exercise goals only from 25 weeks to 36 weeks gestation (F (2, 57) = 1.47, $p = 0.24$, $\eta_p^2 = 0.05$, observed power = 0.30). Although not significant, fewer women dropped out of Group C ($n = 6$, 21%) than Groups A ($n = 12$, 41%) and B ($n = 10$, 33%; χ^2 (2, $N = 88$) = 2.91, $p = 0.23$, Cramer's $V = 0.18$). Adherence data are presented in Table 3.

Exit Survey Results

Overall, there was no difference between groups when asked to rank the difficulty level of both nutrition and exercise (F (2, 55) = 1.56, $p = 0.22$, $\eta_p^2 = 0.05$, observed power = 0.32). Twenty-nine percent, ($n = 5$), 40% ($n = 8$), and 65% ($n = 15$) indicated that nutrition was "easy" or "very easy" in Group A,

Table 3 Program adherence and responses to exit survey for each strategy completed at the end of the intervention. All data presented as mean ± sd (95% confidence intervals) unless otherwise indicated

	Group A (simultaneous) $n = 17$	Group B (nutrition first) $n = 20$	Group C (exercise first) $n = 23$	Effect size
Full program adherence (%)	60.9 ± 17.9 [51.6, 70.1]	66.8 ± 16.7 [58.9, 74.6]	80.2 ± 14.7*[73.8, 86.5]	*0.21*
Adherence from beginning of program to 25 weeks gestation (%)	68.8 ± 17.0 [60.1, 77.6]	-----	-----	
Adherence to nutrition only	67.6 ± 16.3 [59.2, 76.0]	72.6 ± 20.9 [62.9, 82.5]	-----	0.02
Adherence to exercise only	76.1 ± 18.2 [66.7, 85.4]	-----	86.1 ± 15.0* [79.6, 92.6]	0.09
Program adherence from 25 weeks to 36 weeks gestation (%)	53.2 ± 21.8 [42.0, 64.5]	63.0 ± 17.7 [54.8, 71.3]	74.3 ± 17.9* [66.5, 82.0]	*0.18*
Adherence to nutrition only	56.6 ± 21.4 [45.6, 67.6]	66.7 ± 19.1 [57.8, 75.6]	75.1 ± 22.3^{+} [65.3, 84.9]	*0.13*
Adherence to exercise only	62.6 ± 29.6 [47.4, 77.8]	65.8 ± 21.3 [55.9, 75.8]	74.5 ± 19.0 [66.3, 82.7]	*0.05*
Nutrition difficulty (/5)	3.0 ± 0.7 [2.7, 3.4]	3.3 ± 1.1 [2.7, 3.8]	3.5 ± 0.9 [3.2, 4.0]	*0.05*
Exercise difficulty (/5)	3.4 ± 1.2 [2.7, 4.0]	3.7 ± 0.8 [3.3, 4.1]	3.9 ± 0.9 [3.5, 4.3]	*0.05*
Preferred the order received? (*n*; %)				
Yes	11; 65	4; 21	12; 55	*0.28*

Group A both nutrition and exercise introduced simultaneously; Group B nutrition introduced first followed by sequential introduction of exercise at 25 weeks gestation; Group C exercise introduced first followed by sequential introduction of nutrition at 25 weeks gestation. All women followed both behavior changes until the end of the program. Nutrition and exercise difficulty scored on a scale of 5 where 1 = Very Difficult, 2 = Difficult, 3 = Neutral, 4 = Easy, 5 = Very Easy. Adherence from the beginning of the program to 25 weeks for Group B is nutrition data only, for Group C is exercise data only and Group A includes both nutrition and exercise

*$p < 0.05$ comparing Group C with Group A and Group B

$^{+}$ $p < 0.05$ comparing Group C with Group A

Large and medium effect sizes are depicted in italics referring to Cohen's (1988, 1992) criteria: Cohen's *d* for Student's *T* Test: small = 0.20, medium = 0.50, large = 0.80; Cramer's *V* for chi-square analysis: small = 0.10, medium = 0.30, large = 0.50; and partial eta squared for one-way ANOVA: small = 0.01, medium = 0.06, large = 0.14

Group B, and Group C, respectively. Fifty-three percent ($n = 9$), 70% ($n = 11$), and 73% ($n = 17$) indicated that exercise was "easy" or "very easy" in Group A, Group B, and Group C, respectively. Although not significant, more women in Group A ($n = 11$, 65%) and Group C ($n = 12$, 55%) indicated that they received the order of the intervention they would have preferred than women in Group B ($n = 4$, 21%; χ^2 (4, $N = 58$) = 8.86, $p = 0.06$, Cramer's $V = 0.27$). Table 3 includes data from the exit survey.

Health Outcomes (Gestational Weight Gain and EGWG on the Program, Birthweight, Macrosomia, and LBW)

There was a significant difference in gestational weight gain from program entry to delivery (F (2, 57) = 3.22, $p = 0.04$, $\eta_p^2 = 0.10$, observed power = 0.59) as Group C gained significantly less weight (7.7 ± 2.2 kg) than Group B (9.8 ± 2.8 kg, $p = 0.04$) but not Group A (9.1 ± 3.5 kg, $p = 0.35$) while engaged in the intervention strategies. There was no significant difference between the three groups for the number of women who exceeded gestational weight gain guidelines (χ^2 (2, $N = 60$) = 0.95, $p = 0.62$, Cramer's $V = 0.13$). From program entry to 25 weeks gestation, there were no significant differences observed for gestational weight gain (F (2, 57) = 1.15, $p = 0.33$, $\eta_p^2 = 0.04$, observed power = 0.24) and the number of women who exceeded gestational weight gain recommendations (χ^2 (2, $N = 60$) = 1.25, $p = 0.53$, Cramer's $V = 0.15$). There was no significant difference in birthweight among the three groups (F (2, 57) = 2.17, $p = 0.12$, $\eta_p^2 = 0.07$, observed power = 0.43). There was no significant difference in the incidence of macrosomia between the three groups (χ^2 (2, $N = 57$) = 4.92, $p = 0.09$, Cramer's $V = 0.29$) and there were no cases of LBW in all groups. All babies were born at term (> 37 weeks gestation). Gestational weight gain and birthweight

Table 4 Health outcomes: gestational weight gain on the program and birthweight for all strategies. All data presented as mean ± sd (95% confidence intervals), unless otherwise indicated

	Group A (simultaneous) $n = 17$	Group B (nutrition first) $n = 20$	Group C (exercise first) $n = 23$	Effect size
Weight gain from program entry to delivery (kg)	9.1 ± 3.5 [7.4, 11.0]	9.8 ± 2.8 [8.5, 11.2]	7.7 ± 2.2* [6.8, 8.7]	*0.10*
Gestational weight gain above recommendations (*n*, %)	4; 24	6; 30	4; 17	*0.13*
Weight gain from program entry to 25 weeks gestation (kg)	4.2 ± 1.9[3.2, 5.2]	3.8 ± 1.6 [3.1, 4.6]	3.4 ± 1.6 [2.9, 3.9]	0.04
Gestational weight gain above recommendations (*n*, %)	6; 35	9; 45	8; 35	*0.15*
Birthweight (g)	3539 ± 540 [3261, 3817]	3392 ± 311 [3246, 3538]	3262 ± 394 [3091, 3432]	*0.07*
Macrosomia (*n*, %)	3; 18	0; 0	1; 4	*0.29*
Low birthweight (*n*, %)	0; 0	0; 0	0; 0	

Group A both nutrition and exercise introduced simultaneously; Group B nutrition introduced first followed by sequential introduction of exercise at 25 weeks gestation; Group C exercise introduced first followed by sequential introduction of nutrition at 25 weeks gestation. All women followed both behavior changes until the end of the program. Macrosomia was defined as birthweight > 4000 g; low birthweight was defined as birthweight < 2500 g

*$p < 0.05$ comparing Group C with B

Large and medium effect sizes are depicted in italics referring to Cohen's (1988, 1992) criteria: Cohen's d for Student's *T* Test: small = 0.20, medium = 0.50, large = 0.80; Cramer's V for chi square analysis: small = 0.10, medium = 0.30, large = 0.50; and partial eta squared for one-way ANOVA: small = 0.01, medium = 0.06, large = 0.14

data are presented in Table 4. There were no adverse effects or harms as a result of the intervention to report.

Discussion

The results of the current study suggested that sequential introduction of exercise first followed by nutrition significantly increased adherence to program recommendations during pregnancy. Nutrition may potentially be a more challenging intervention than exercise. Compared with exercise, fewer women ranked nutrition as "easy" or "very easy" on the exit survey and fewer women indicated that they preferred to be in the nutrition first group. It has been suggested that performing exercise first can be a gateway to nutrition interventions [27, 28]. Perhaps, mastering one change (exercise) improves motivation to then also complete the second intervention (nutrition), which results in overall improved adherence to a multiple behavior change program. In the current study, we saw that all groups had a decline in their adherence as the program progressed from the beginning of the intervention to 25 weeks and from 25 weeks to 36 weeks gestation; however, overall adherence for Group C remained higher in comparison with both Groups A and B even when the nutrition behavior change goals were added.

The current study also found a significant difference in lower weight gain that favored Group C over Groups B and A. These results are supported by McDonald et al. (2016) as they found that studies with higher adherence were more likely to show a significant difference favoring the intervention group for lower gestational weight gain than studies that had poor adherence [43]. Additionally, there were non-significant small–medium effects that favored Group C for the prevention of EGWG from program entry to delivery and for incidence of macrosomia, suggesting that the sequential approach may be superior to the simultaneous behavior change approach for improving health outcomes during pregnancy. This is in line with findings from a recent meta-analysis that used individual patient data as they found a small positive effect of exercise interventions during pregnancy on preventing EGWG [44]. Previous research however has suggested that dietary changes may be more favorable in comparison with exercise for improving health outcomes during pregnancy, including promotion of appropriate gestational weight gain [8, 43]. Overall, our findings suggested that the sequential approach with exercise introduced first can increase program adherence to both nutrition and exercise recommendations and as a result, more women may be likely to achieve desired health outcomes including controlling gestational weight gain, prevention of EGWG, and macrosomia.

There is no gold standard for measuring adherence to lifestyle interventions [16]. Common methods, often used to report adherence in medical trials, are program completion

(retention) and attrition [16]. In the current study, although not statistically significant, fewer women dropped out of Group C than both A and B, suggesting adherence and program completion were higher in Group C with more women able to continue to commit to the program.

To our knowledge, this is the first study to assess the sequential versus simultaneous approach to introducing a lifestyle intervention during pregnancy with program adherence as the primary outcome. We used an adherence measurement tool that was designed specifically for the study, incorporated both the nutrition and exercise goals of the intervention and was scored on a weekly basis. Furthermore, this adherence tool can be modified for other studies simply by changing the scoring system to reflect the goals of the intervention. Our study was adequately powered to detect a difference between the three groups for full program adherence (primary outcome). In addition, adherence was examined in two ways, all participants were followed and scored for adherence on a weekly basis with complete data for program adherence. In addition, adherence was considered and measured as retention to the behavior change strategies. Other strengths included the incorporation of an exit survey on participant preference and perceived difficulty of the interventions as factors that may influence adherence. Another strength is that all three groups had the same number of face-to-face visits with study investigators. Limitations of the current study included the use of self-reported measurement tools (nutrition and exercise logs) to complete the scoring of adherence. Self-reporting may have led to under- or over-reporting of nutrition and exercise behaviors. As well, the self-reporting measurement tools may have actually contributed to increasing adherence as self-monitoring has been shown to be an effective strategy for nutrition and exercise behavior change [45]. We may have inadvertently improved adherence to the intervention by asking women to self-monitor their behaviors. Further research to evaluate the exact mechanisms that may have contributed to improving adherence, such as self-monitoring, should be explored. Additionally, the exit survey was not validated. It may also be valuable to update the exit survey to include qualitative responses to better understand adherence to the nutrition and exercise goals from the participant's perspective. Additionally, the current study was not powered to detect significant differences for the health outcomes evaluated. Future interventions can use the results from the current study to determine an adequate sample size to test the effectiveness of the simultaneous or sequential approaches on specific health outcomes with the assessment of program adherence. Furthermore, there is opportunity to enhance the adherence measurement tool to include personalized behavior change goals in addition to the generic goals for the full program. Finally, the demographics of women included were mostly Caucasian, had received higher education, and had self-selected to participate in a lifestyle intervention before randomization; therefore, the results may not be generalizable to all diverse pregnant populations.

In conclusion, adherence to intervention goals during pregnancy was improved by introducing exercise first followed by nutrition. Improving adherence to nutrition and exercise interventions during pregnancy may promote positive health outcomes. Future studies should aim to encompass a more diverse sample and adherence should be measured and reported in all lifestyle interventions during pregnancy. By increasing adherence to nutrition and exercise goals during pregnancy, the efficacy of interventions may improve and increase overall achievement of positive health outcomes for both mom and baby.

Funding Information TSN, MM, and KH are funded by an Ontario Graduate Scholarship. RB is funded by Whaley and Harding Fellowship-Children's Health Research Institute and Western Fellowship Program.

Compliance with Ethical Standards

Conflict of Interest All authors declare that they have no conflicts of interest.

Ethical Approval The research protocol was reviewed and approved by the Western University Human Research Ethics Board and all participants gave written informed consent.

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