Modeling the Impact of Prepregnancy BMI, Physical Activity, and Energy Intake on Gestational Weight Gain, Infant Birth Weight, and Postpartum Weight Retention

Amy E. Montpetit, Hugues Plourde, Tamara R. Cohen, and Kristine G. Koski

Background: A “fit pregnancy” requires balancing energy expenditure with energy intake (EI) to achieve appropriate gestational weight gains (GWG), healthy infant birth weights (IBW), and minimal postpartum weight retention (PPWR). Our objective was to develop an integrated conceptual framework to assess the contribution of prepregnancy weight (PP-BMI), EI, and physical activity (PA) as determinants of GWG, IBW, and PPWR. Methods: Pregnant women (n = 59) were recruited from prenatal classes. Energy intake was estimated using 3 24-hr diet recalls and PA using a validated PA questionnaire and a pedometer. Telephone interviews at 6-weeks postpartum assessed self-reported GWG, IBW, and PPWR. Hierarchical multiple regression analyses were used to explore the potential predictors of GWG, IBW, and PPWR. Results: Prepregnancy BMI was associated with GWG, and EI was associated with IBW; each model captured only 6%–18% of the variability. In contrast, PPWR was predicted by PP-BMI, GWG, and EI, which together explained 61% of its variability, whereas GWG alone explained 51% of the variability in PPWR. Conclusions: Modeling the relationship using hierarchical models suggests that PP-BMI, prepartum PA, and EI differentially impact GWG, IBW, and PPWR. Keywords: nutrition, exercise, pedometers, healthy lifestyle

Pregnancy is the period in a woman’s life when she may be most conscious of her health and as such, expectant mothers commonly change their behaviors to reflect a more health conscious lifestyle. A ‘fit pregnancy’ can be attained when a woman is able to balance energy intake and energy expenditure to achieve an appropriate gestational weight gain. The benefits of a ‘fit pregnancy’ extend beyond the mother during pregnancy as a ‘fit pregnancy’ also promotes healthy infant birth weights and minimizes maternal postpartum weight retention. Excessive gestational weight gain (GWG) during pregnancy is now considered a risk factor for the development of obesity, since a woman’s prepregnancy BMI can influence her gestational weight gain, infant birth weight, and postpartum weight retention. Evidence suggests that women who present as overweight or obese before pregnancy are at an increased risk of experiencing higher gestational weight gains, giving birth to heavier infants, and retaining more weight postpartum. While some women may stop smoking during pregnancy, women’s lifestyles, such as engaging in regular physical activity, do not readily change once pregnancy begins. In fact, most women’s level of physical activity declines from the first to the third trimester, resulting in more women classified as sedentary during pregnancy. Physical activity recommendations have been developed for the pregnant population, but despite these recommendations, uniformly convincing evidence surrounding weight gain remains elusive. Whereas physical activity during pregnancy in some studies resulted in lower gestational weight gains, a few studies show otherwise. Exercising at higher intensities (> 50% maximum heart rate) or higher frequencies (> 7 days) has been shown to decrease infant birth weight anywhere from 86–500 g compared with women not participating in such routines. However it should be noted that these women did not deliver “low birth weight” infants. Low birth weight is
considered to be infants who weigh less than 2500 g at birth; infants in these studies had healthy birth weights ranging from 2700–4000 g. Lastly, although physical activity during pregnancy may aid in controlling excessive postpartum weight retention, intervention trials with aims of promoting physical activity and appropriate energy intakes to reduce postpartum weight retention have proven both successful and unsuccessful.

Energy intakes during pregnancy impact gestational weight gain and infant birth weight. Two randomized control trials have reported success in preventing excessive gestational weight gain. Polley et al randomized normal weight women by BMI and race and assigned them to either an intervention group that focused on healthy eating, exercise and individualized gestational weight gain recommendations or to a control group. This study found less weight gain (15.4 kg ± 7.1) in the intervention group compared with control (16.4 kg ± 4.8) in normal-weight women. Similarly, a study by Wolff et al randomized obese women to an intervention group that received dietary counseling and a control group that did not receive counseling. In this study, the intervention group gained significantly less weight (6.6 kg ± 5.5) compared with the control (13.3 kg ± 7.5). In addition, Olson et al reported higher weight gains in women who increased their energy intakes during pregnancy compared with those whose intakes stayed the same, or decreased. Although energy requirements during pregnancy have not been published, estimated energy requirements for pregnant women are based on their prepregnancy physical activity level, age, weight, and height, and are adjusted according to trimester. Specifically, women are encouraged to start increasing their energy intakes in their second (340 kcal) and third trimesters (452 kcal) only.

The use of hierarchical models have previously been used to assess the impact of health behaviors during pregnancy on gestational weight gain. To our knowledge a similar integrated framework has not been used to examine the influences of pregnancy behaviors on infant birth weight and postpartum weight retention. Therefore, the objective of this study was to develop an integrated conceptual behavioral model to assess the impact of prepregnancy weight (PP-BMI), energy intake (EI) and physical activity (PA) as determinants of 1) gestational weight gain (GWG), 2) infant birth weight (IBW), and 3) postpartum weight retention (PPWR).

Methods

Subject Protocol

Ethics approval was obtained from McGill University, Ottawa Public Health Research Ethics Board, Centre de Santé et de Services Sociaux (CSSS) West Island and CSSS Cavendish. Of the 142 women approached through public health prenatal classes in Ottawa (ON) and Montreal (QC), 81 (52%) were recruited from August to December 2008. Inclusion criteria were women 18–40 yrs old, who presented in their second or third trimester and were free of contraindications to exercise during pregnancy.

Pregnancy Assessment

Women were visited at their home or workplace where informed consent was obtained. Women were asked to self-report age, height, date of last menses, and prepregnancy weight. Women were instructed how to use a pedometer, complete the logbook and use a dietary interview kit. In addition, women completed a detailed questionnaire which provided information on sociodemographics and physical activity practices. Current physical activity was assessed using the Pregnancy Physical Activity Questionnaire (PPAQ). The PPAQ is a validated self-administered questionnaire that asks women to report estimated time spent on 32 activities per day, including household/care giving, occupational, sport/exercise, transportation, and inactivity. Each activity is assigned an intensity value that is multiplied by the duration of the activity, which allows for conversion to metabolic equivalents (METs), daily energy expenditure (kcal), and MET-hr/wk. The Joint SOCG/CSEP Clinical Practice Guidelines for exercise during pregnancy were translated to a value of 8.5 MET-hr/wk to be used as a cut-off to classify women as low active (< 8.5 MET-hr/wk) or active (> 8.5 MET-hr/wk).

Dietary intake was collected via 3 24-hour telephone food recalls on nonconsecutive days the same week the women wore the pedometer. Dietary interview kits were provided to assist with estimating food intake. Each kit included a ruler and a styrofoam bowl, plate, and cup with premeasured portion sizes. The Canadian Nutrient File 2007 and ESHA Research Food Processor (version 9.1; Salem, OR) were used to analyze food recalls for total energy (kcal), protein (g), fat (g), and carbohydrate (g). Participants were asked to wear the ‘New Lifestyles Digi-Walker SW 200 Pedometer’ (Less Summit, MO, USA) for 1 week and to record daily steps in a pedometer logbook. The New Lifestyles Digi-Walker SW 200 was chosen because it has been tested for accuracy and validity. Despite its inability to measure exercise intensity, pedometers have been widely used because they are an inexpensive and reliable way to objectively measure PA. Furthermore, as walking is the most reported activity during pregnancy, this assessment tool was considered ideal for this study. Currently, there are no step recommendations for the pregnant population, therefore American College of Sports Medicine (ACSM) cutoffs for the normal population were used. This classified participants by their average daily step count as sedentary (< 5000 steps/day), low active (5000–7499 steps/day) or active (> 7500 steps/day).

Postpartum Assessment

Women were telephoned at 6-weeks postpartum and self-reported the following: gestational weight gain,
infant gestational age, birth weight and gender, breastfeeding practices, and current postpartum weight. Total gestational weight gain was calculated by subtracting the women’s prepregnancy weight from their predelivery weight. Postpartum weight retention was defined as a woman’s weight at 6-week postpartum minus her prepregnancy weight. As we did not have access to medical charts, women were asked to recall their measured weight from their routine 6 weeks postpartum visit to their doctor. This early time point (6 wks) usually represents the maximal adiposity gained during pregnancy and can be used as an early indicator of adipose tissue accumulation occurring during pregnancy that is not influenced either by blood volume changes and/or planned weight loss.3,44

Statistical Analysis

SAS [Version 9.2, 2002–2003] (SAS Institute Inc., Cary, NC) was used for data analysis, with statistical significance set at \( P < .05 \). Data were log transformed and tested for normality. Pearson correlation coefficients were used to indicate the strength and direction of possible associations between variables. Hierarchical multiple regression analyses were used to explore the potential predictors of gestational weight gain (GWG), infant birth weight (IBW), and postpartum weight retention (PPWR).

Results

Population Characteristics

A total of 81 women consented to participate in the study. Our sample consisted of well-educated (68% with university degree), married women (32 ± 4 yrs) with family incomes above $50,000 (78%) %), in their second or third trimester of pregnancy (27 ± 6 weeks gestation) who were attending public prenatal classes in Ottawa, Ontario, and Montreal, Quebec. Sixty-one women (75%) completed pedometer logbooks, 74 (91%) participated in telephone dietary recalls, and 78 (96%) completed the postpartum assessment; 59 women completed all aspects of the study and were used in this analysis. Our women were predominantly sedentary or low-active (70% < 7500 steps/day; 69% < 8.5 MET-hr/wk), were eating above their recommended daily energy intake (54%) and exceeded their GWG recommendations (54%). Women who walked more presented with lower GWG (\( r = -0.26, P = .049 \)) and lower PPWR (\( r = -0.31, P = .019 \)) (Table 1).

Individual variability existed among all outcomes (Figure 1). Variability in prepregnancy weight ranged from 48–100 kg (Figure 1A) with 72% classified before pregnancy as normal weight (BMI < 25 kg/m²), 25% as overweight (BMI 25–29.9 kg/m²), and 3% as obese (BMI > 30 kg/m²). Usual daily energy intake(s) ranged between 1079–3763 kcal/d (Figure 1B), where comparisons of individual energy intakes to estimated energy requirements (EER) revealed that 54% of the women were eating in excess of their requirements. Figure 1C outlines the variability in daily pedometer step counts (844–11,089 steps/d); 27% were classified as sedentary (< 5000 steps/day), 43% as low active (5000–7500 steps/day), and 30% as active (> 7500 steps/day). No differences were found in number of steps per day when compared across prepregnancy BMI categories. Variability in weekly physical activity using metabolic equivalents ranged from 6–9.9 MET-hr/wk. According to the ACOG/CSEP recommendations,21 69% of our pregnant mothers were classified as sedentary or low-active (< 8.5 MET-hr/wk) and 31% as active (>8.5 MET-hr/wk).

Infant Birth Weight

Infant birth weight, which ranged from 2579–4706 g (Figure 1D), was positively correlated with energy intake (Table 1). Table 2 summarizes the hierarchical determinants of IBW. The first level multiple linear regression model that included gestational weight gain as the only variable did not reach significance (\( P = .069 \)). However, with steps and EI added to the model,

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Correlations Between Variables of a Fit Pregnancy and Pregnancy Outcomes (N = 59)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gestational weight gain (kg)</td>
</tr>
<tr>
<td>Variable</td>
<td>( r )</td>
</tr>
<tr>
<td>Prepregnancy BMI (kg/m²)</td>
<td>0.35*</td>
</tr>
<tr>
<td>Energy intake (kcal)</td>
<td>0.11</td>
</tr>
<tr>
<td>Steps/d</td>
<td>-0.26*</td>
</tr>
<tr>
<td>Met-h/wk</td>
<td>0.04</td>
</tr>
<tr>
<td>Gestational weight gain (kg)</td>
<td>–</td>
</tr>
<tr>
<td>Infant birth weight (g)</td>
<td>0.23</td>
</tr>
<tr>
<td>Postpartum weight retention (kg)</td>
<td>0.72*</td>
</tr>
</tbody>
</table>

* Correlation \( (r) \) is significant at \( P \leq .05 \).
EI but not steps entered as a significant predictor of infant birth weight. In the third level of analysis, with prepregnancy BMI added to the model, EI still remained in the model as a significant determinant. However, this final model only captured 18% of the variability in IBW.

**Gestational Weight Gain**

Figure 1E describes the variability in GWG (9 to 34 kg), where 54% of women exceeded gestational weight gain recommendations. Gestational weight gain was positively correlated with prepregnancy BMI and negatively...
correlated with steps (Table 1). Table 3 outlines the determinants of GWG. The first level multiple linear regression model included steps and EI with only steps emerging as a significant negative predictor of gestational weight gain ($P = .044$). However, in the second level of analysis, when prepregnancy BMI was added to the model, steps were no longer significant and prepregnancy BMI remained as the only significant variable ($P = .016$). This final model explained 18% of the variance in GWG.

**Postpartum Weight Retention**

Figure 1F describes the variability of PPWR at 6-weeks postpartum, which ranged from –2.3 to 20.5 kg. The majority (90%) was breastfeeding and there was no difference in weight loss between women who did or did not breastfeed. The correlation matrix showed that PPWR was negatively correlated with steps and positively correlated with gestational weight gain (Table 1). Table 4 outlines the regression analysis used to model the hierarchical determinants of PPWR. In the first model, gestational weight gain was the only predictor of PPWR in the model and captured 51% of the variability. In the second level of analysis, which included energy intake and steps, gestational weight gain remained significant, but energy intake also emerged as an independent predictor ($P = .025$). In the third level of analysis, when prepregnancy BMI was introduced to the model, gestational weight gain and energy intake remained significant, but prepregnancy BMI emerged as an important predictor ($P = .022$). This final model explained 61% of the variance in PPWR.

**Discussion**

The novelty of this study is that it examined 3 outcomes of pregnancy (gestational weight gain, infant birth weight, and postpartum weight retention) using hierarchical modeling to determine behaviors that should

### Table 2 Predictors of Infant Birth Weight Through Hierarchical Multiple Regression Analysis (N = 59)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>$P$</td>
<td>Beta</td>
</tr>
<tr>
<td>Gestational weight gain (kg)</td>
<td>18.5</td>
<td>0.069</td>
<td>16.1</td>
</tr>
<tr>
<td>Physical activity$^a$ (per 1000 steps/d)</td>
<td>–</td>
<td>–</td>
<td>5.5</td>
</tr>
<tr>
<td>Energy intake$^b$ (per 1000 kcal/d)</td>
<td>–</td>
<td>–</td>
<td>307.0$^*$</td>
</tr>
<tr>
<td>Prepregnancy BMI (kg/m$^2$)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

$R^2$ 0.06 0.14 0.18

$F$ 3.43 2.98$^*$ 2.83$^*$

$P, r > F$ 0.069 0.039 0.033

* Significant at $P \leq .05$.

$^a$ Interpretation: the Beta coefficient represents IBW per every 1000 steps per day.

$^b$ Interpretation: the Beta coefficient represents IBW per every per 1000 kcal per day.

### Table 3 Predictors of Gestational Weight Gain Through Hierarchical Multiple Regression Analysis (N = 59)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>$P$</td>
</tr>
<tr>
<td>Physical activity$^a$ (per 1000 steps/d)</td>
<td>–0.78$^*$</td>
<td>0.044</td>
</tr>
<tr>
<td>Energy intake$^b$ (per 1000 kcal/d)</td>
<td>1.66</td>
<td>0.338</td>
</tr>
<tr>
<td>Prepregnancy BMI (kg/m$^2$)</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

$R^2$ 0.08 0.18

$F$ 2.47 3.85$^*$

$P, r > F$ 0.094 0.014

* Significant at $P \leq .05$.

$^a$ Interpretation: the Beta coefficient represents GWG per every 1000 steps per day.

$^b$ Interpretation: the Beta coefficient represents GWG per every per 1000 kcal per day.
be targeted when planning lifestyle interventions for pregnant women (Figure 2). Our major findings are summarized as follows: 1) energy intake was the most significant determinant of infant birth weight in our relatively sedentary, well-educated, nulliparous population, where it captured 6%–18% of the variability; 2) we also captured 8%–18% of the variability of gestational weight gain, which was modeled using prepregnancy BMI and prepartum physical activity (steps); and 3) we were able to explain 61% of the variability in postpartum weight retention using prepregnancy BMI, gestational weight gain, and energy intake. Together these models would suggest that interventions aimed at promoting ‘fit pregnancies’ should focus on attaining a healthy prepregnancy BMI, emphasize prepartum physical activity, and stress appropriate energy intakes during pregnancy. As also suggested by previous authors, we confirm that following these 3 explicit and attainable behaviors, pregnant women can reduce excessive gestational weight gains, avoid oversized infants, and lessen their chances of becoming overweight or obese postpartum.

The women in this study were healthy, nulliparous, and well-educated pregnant women of high socioeconomic status, meaning they had both the time and the means to be physically active. Therefore it came as a surprise that such a high percentage (70%) of the population were either sedentary or low active. As seen in other studies, women typically do not engage in exercise during pregnancy, as activity levels are generally reported to be quite low. In fact, research acknowledges that pregnant women’s exercise behaviors decrease with the progression of pregnancy. Furthermore, the primary

### Table 4  Predictors of Postpartum Weight Retention Through Hierarchical Multiple Regression Analysis (N = 59)

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>P</td>
<td>Beta</td>
</tr>
<tr>
<td>Gestational weight gain (kg)</td>
<td>0.59*</td>
<td>&lt;.0001</td>
<td>0.58*</td>
</tr>
<tr>
<td>Physical activitya (per 1000 steps/d)</td>
<td>–</td>
<td>–</td>
<td>–0.28</td>
</tr>
<tr>
<td>Energy intakeb (per 1000 kcal/d)</td>
<td>–</td>
<td>–</td>
<td>–2.13*</td>
</tr>
<tr>
<td>Prepregnancy BMI (kg/m²)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>R²</td>
<td>0.51</td>
<td></td>
<td>0.57</td>
</tr>
<tr>
<td>F</td>
<td>58.4*</td>
<td></td>
<td>23.2*</td>
</tr>
<tr>
<td>P₃ &gt; F</td>
<td>&lt;.0001</td>
<td></td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

* Significant at P ≤ .05.

a Interpretation: the Beta coefficient represents PPWR per every 1000 steps per day.

b Interpretation: the Beta coefficient represents PPWR per every per 1000 kcal per day.

![Figure 2 — Model for determining pregnancy behaviors that modulate gestational weight gain, postpartum weight retention, and infant birth weight.](image)
reasons for engaging in physical activity during pregnancy was not to help control gestational weight gain, but to prevent health complaints such as nausea and improve fitness and psychological well-being, as has been suggested by others.23,47

**Infant Birth Weight**

As previously established by Kramer et al,6 the determinants of birth weight in developed countries include smoking, prepregnancy weight, and gestational nutrition. Two of these determinants, prepregnancy weight and energy intake, were assessed in our study, but only energy intake emerged as a predictor of infant birth weight. Neither inadequate nutrition nor low birth weights were of concern in this study as more than half of the mothers (54%) consumed energy intakes in excess of their estimated energy requirements (EER) and 83% of the infant birth weights were within normal range; the remainder (17%) were classified as large-for-gestational age. In 1970, the National Research Council established the EER for pregnancy with the goal of improving infant birth weights.48 Since then however, more women are presenting in pregnancy as overweight and obese, thereby increasing the risk of delivery complications, large-for-gestational age infants, and postpartum obesity. This shift in the pregnancy profile has lead to a revision of the GWG guidelines.1 Our hierarchical models show that increasing energy intake during pregnancy may contribute to higher birth weights, and more caution and constraints with regards to monitoring energy intake to prevent large-for-gestational age births is warranted.

**Gestational Weight Gain**

When assessing physical activity during pregnancy, most studies have used validated questionnaires,49–51 some have used objective measures such as the pedometer,28,41 and few have employed both.7 In this study we examined the impact of both steps and METs on total gestational weight gain and found only a weak association with steps, which we attribute to the low physical activity level of our sedentary population. Other studies have also found associations between gestational weight gain and physical activity.10,12,15,22,24,28 Previously, Cohen et al7 reported that METs were related to the rate of GWG. Dose-response relationships are particularly helpful when trying to determine the effects of physical activity on pregnancy outcomes. However, as noted by researchers,36 physical activity questionnaires prevent this type of assessment and are subject to recall bias; this may be why pedometers overcome these limitations.

In our hierarchical model, we also found that prepregnancy BMI was related to gestational weight gain. Literature has previously described this relationship and this evidence was used to support the most recent Institute of Medicine’s gestational weight gain recommendations.1 Physical activity recommendations for the pregnant population have recently been developed,21 but have not been uniformly adopted by health professionals,7 and step recommendations have yet to be established for the pregnant population. As physical activity in the form of steps entered into our hierarchical models, and walking was the most commonly reported activity during pregnancy,40–42 the development of pregnancy step recommendations is warranted to foster fit pregnancies and modulate gestational weight gain.

**Postpartum Weight Retention**

Literature suggests that prepregnancy BMI is a predictor of postpartum weight retention.52 More recently, Walker et al17 and Amorim et al3 found higher postpartum weight retentions in women with higher prepregnancy weight, whereas others have reported that prepregnancy weight was not related to postpartum weight retention.13 In contrast to these studies, a higher prepregnancy BMI was associated with lower postpartum weight retention in our study, however given that the majority (72%) of our population initially presented with normal BMIs, and that nearly half of those gained in excess of the gestational weight gain recommendations (42%), this result is to be expected. Furthermore, the number of women classified as overweight or obese doubled from 23%–46% following delivery, making pregnancy a significant risk factor for adult obesity in our study and is supported by others.45

In addition to prepregnancy weight, excessive gestational weight gain has been identified as a significant risk factor of postpartum weight retention.5–5 Literature shows that women who experience higher gestational weight gains are at increased risk of retaining more weight postpartum,8,13,53–57 particularly if the weight is gained in the first trimester.18 A review by Walker et al3 found similar associations between gestational weight gain and postpartum weight retention, and reported that less than one-third of women return to their prepregnancy weight at 6 weeks postpartum. Women who exceeded gestational weight gain means58 or medians18 had higher weight gains in all trimesters, as well as higher weight retentions at 6-wks and 3-months postpartum. Moreover a meta-analysis showed that as early as 6-wks postpartum, mothers weighed more and had higher BMI than at any other postpartum time period.5 After this time point, women’s weights were affected by ethnicity, lactation, nutrition, and physical activity interventions.3–5,59,60 Furthermore, women who retain more weight are found to be at an increased risk of repeating this pattern in future pregnancies.8

We found, using hierarchical models, that gestational weight gain was the strongest predictor of postpartum weight retention, capturing 51% of the variability. In addition, not all women in our study were following the IOM gestational weight gain recommendations. As others have shown, women who follow IOM guidelines report better pregnancy outcomes,35,61 whereas women who exceed gestational weight gain recommendations
retain more weight\textsuperscript{8} and are 3 times more likely to remain overweight postpartum.\textsuperscript{62}

Both energy intake and physical activity during pregnancy are indirectly associated with postpartum weight retention.\textsuperscript{28,31} Interesting to our study was the finding that energy intake was negatively associated with postpartum weight retention, suggesting that women with higher postpartum weight retention, having already exceeded their targeted weight gains, may have intervened by decreasing their energy intakes or increasing their physical activity in the second and third trimesters. Both strategies can lower gestational weight gain and potentially minimize postpartum weight retention. However, there are currently very few intervention trials aimed at reducing postpartum weight retention. A recent intervention trial by Mottola et al\textsuperscript{28} found that a nutrition and exercise program, conducted in the second half of pregnancy and extending into the postpartum period, helped to minimize the postpartum weight retention of overweight and obese women. Our results would indicate that programs emphasizing both energy intakes and physical activity may need to be extended to women with normal BMIs, as these women often exceed IOM gestational weight gain recommendations.

Thus the focus on minimizing postpartum weight retention needs to begin with weight management both before and during pregnancy. Deferring weight loss to the postpartum period rather than preventing it before and during pregnancy appears to be common practice, but has serious consequences. Research has found that women who gain excessively are at an increased risk of terminating breastfeeding early.\textsuperscript{63} In addition, women often overestimate the impact of lactation on weight loss altogether\textsuperscript{64} and increased time constraints limit participation in sport and physical activity programs once the baby arrives home.\textsuperscript{23}

**Limitations**

This study presents with limitations. Nearly 30\% of mothers did not complete their pedometer log books. Second, the homogeneity of our population, which was predominantly sedentary, contributed toward less variability in the physical activity measures. Nevertheless, steps was negatively correlated with both gestational weight gain and postpartum weight retention, and entered in several hierarchical models, suggesting that if more women had increased their volume of walking, physical activity may have emerged as a more significant determinant of our outcomes. Moreover, the role of physical activity in the 3 models may have been lessened because many of these same women exceeded their estimated energy requirements and gained in excess of IOM recommendations. Furthermore, energy intake was a negative predictor of postpartum weight retention in our study, and while this opposes our hypotheses, it may be explained by the misreporting of dietary intake in pregnant\textsuperscript{65} or weight conscious\textsuperscript{66} women. Future research with larger sample sizes is warranted.

**Conclusion**

Our hierarchical models show a complex interrelationship among gestational weight gain, physical activity and energy intake, suggesting that different intervention strategies may be required to achieve a ‘fit pregnancy.’ Our results show that achieving a healthy prepregnancy BMI (18.5–24.9 kg/m\textsuperscript{2}), increasing prepregnancy physical activity levels, and consuming appropriate energy intakes may help avoid excessive gestational weight gain and hence, minimize postpartum weight retention. Likewise controlling energy intakes during pregnancy may be sufficient to minimize delivery of a large-for-gestational age infant, particularly for normal and overweight women.

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