Postpartum weight loss

and infant feeding

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ABSTRACT

It is not yet clear whether women who lactate lose the weight gained during pregnancy faster than their nonlactating counterparts. The primary objective of this study was to look for any important differences in the rate of postpartum weight loss in the first 9 months postpartum according to method of infant feeding.

Two hundred thirty-six women attending two public health clinics in Montreal were weighed in one to four encounters occurring at different stages of the postpartum period but no later than the 9th month postpartum. A questionnaire assessing the method of infant feeding (predominantly breastfee ling, mixed feeding or predominantly bottlefeeding) and potential confounders was administered by telephone after each weighing. An unbalanced multivariate repeate i measures analysis revealed no statistically significant differences in the rate of weight loss by category of infant feeding. Gestational weight gain, postpartum smoking and maternal birthplace were important predictors of postpartum weight change.

RÉSUMÉ

Il n'y a pas encore d'évidence certaine qui indique que les femmes qui allaitent perdent du poids plus rapidement que celles qui n'allaitent pas. L'objectif principal de cette étude était d'analyser les différences importantes dans le taux de perte de poids dans les premiers neuf mois post-accouchement selon la méthode d'alimentation du bébé.

Le poids de deux cent trente six femmes consultant deux cliniques de santé publique de Montréal, a été mesuré entre une et quatre fois lors de rencontres survenant à différentes périodes post-accouchement; en aucun temps,les périodes de suivi n'ont dépassé neuf mois post-accouchement. Un questionnaire concernant la méthode d'alimentation (principalement allaitement maternel, alimentation mixte et principalement alimentation au biberon) et les facteurs confondants potentiels a été demandé par téléphone après chacune des prises de poids. Une analyse multivariée des mesures répétées déséquilibrées n'a pas montré de différences statistiquement significatives dans le pourcentage de perte de poids par catégorie d'allaitement du bébé. Le gain pondéral durant la grossesse, le tabagisme en post-accouchement et le lieu de naissance de la mère étaient tous des prédicteurs importants du changement de poids en post-accouchement.

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1. INTRODUCTION

In the past few decades, researchers, health professionals and the general public have shown an increasing interest in human lactation. Research in this area has focused on the benefits of breastfeeding for the infant, the hormonal control of lactation, the effect of lactation on dietary intake of the mother, and the effect of maternal nutritional status on the composition of breast milk. Fewer studies have examined the effects of lactation on the weight and body composition of well-nourished women Despite differences in methodological approaches, the results of these latter studies have not substantiated the general belief that maternal energy stores deposited during pregnancy are intended primarily to subsidize the cost of lactation; the actual effect of lactation on body weight may vary with different degrees of lactation.

Many studies in the area of maternal nutrition have examined the cycle of fat retention/mobilization during pregnancy and the puerperium. During pregnancy, nonobese women permitted to eat to appetite store 3-4 kg of fat, the majority during the first two trimesters (1). This fat is then mobilized in late pregnancy, providing alternate fuel for oxidation by maternal tissues, and so spares glucose for use by the fetus (2,3). These changes in energy economy help to provide an uninterrupted supply of energy to the growing fetus.

The cycle of fat deposition in early pregnancy followed by fat mobilization in late pregnancy has obvious advantages when the food supply is variable, inasmuch as the energy cost of pregnancy may be distributed over the entire gestational period. In wellnourished women, fat deposition exceeds utilization. Whether a net pregnancy weight gain (i.e., a higher weight after delivery than prepregnancy) should be regarded as physiologic or merely an indication of failure to adjust energy intake to correspond to reduced physical activity is a long-disputed question (2). Hytten et al. have pointed out

that the loss of extra fat deposited during pregnancy--in most women after parturition, whether lactating or not--seems to be part of the natural cycle of adaptation to pregnancy (4).

Two more important and better documented physiologic mechanisms are used to meet the additional energy costs of lactation: an increased energy intake and the utilization of body fat reserves. In most mammals, the stress of lactation induces a larger change in energy flux than occurs at any other time of life. Interestingly, different species have adopted a range of strategies in relation to their energy intake and the use of body fat stores in support of lactation. At one end of the spectrum, certain seals remain on land and eat nothing during lactation, thus supporting the entire cost of milk synthesis and maternal maintenance from their fat stores. The other end of the range is represented by species such as mice and rats with large, fast-growing litters. In these species, the demands of lactation are so large that they must be met by a marked increase in food acquisition. Although these rodent species are in negative energy balance, the contribution of body fat to the total cost of lactation is quantitively negligible (5).

It is difficult to judge where human lactation stands in this continuum. Primates in general, and humans in particular, are characterized by relatively slow rates of postnatal growth, and this is reflected in both the composition and volume of their milk. Estimates of the peak milk energy output as a function of maternal body weight demonstrates that in humans the requirements for milk production are between 4- and 15-fold lower than in the sheep and mouse, respectively (6). It is this very low stress of human lactation per unit time that determines the woman's immediate physiological response. For example, a woman need only increase her food intake by about 25% to meet the full costs of lactation, whereas a rat with 8 or more pups must increase its intake by 300% or more. Measuring the stress of lactation per unit time may exaggerate the differences between primates and other species in terms of the total cost of lactation, since the total cost depends on the duration of lactation. For example, breastfeeding in developing countries commonly continues 2-3 times the length of gestation. This is considerably longer than in most other mammals, and as a consequence the overall costs of lactation in humans may be similar to many species with higher relative daily milk outputs (6)

In developed countries, the duration of breastfeeding in well-nourished women is typically shorter. This is coupled with the presence in these women of large prepregnancy subcutaneous fat deposits that are further increased by fat storage during pregnancy. Furthermore, during lactation lipogenesis tends to be markedly suppressed in adipocytes by a reduction in the number and sensitivity of insulin receptors, a depression in the activity of lipoprotein lipase and fatty acid synthetase and a reduction in the rate of fatty acid reesterification. All these changes tend to shift the equilibrium away from fat deposition and to potentiate a catabolic process that could provide a large proportion of the energy costs of laciation. Despite making good physiologic sense, this metabolic shift does not necessarily occur; in conditions of abundant food supply, for example, increased food intake largely overrides the catabolic effects (6). In contrast, lactating women in developing countries who are unable to meet energy demands of lactation by increasing energy intake or substantially reducing energy expenditure may use their own body fat stores to subsidize the cost of lactation (7).

There are several other potential mechanisms of energy conservation during lactation in addition to the increased energy intake and mobilization of fat stores; these so-called "energy-sparing mechanisms" include changes in the basal metabolic rate (BMR), thermogenesis and physical activity (8). There appears to be no general consensus as to whether the BMR increases, remains the same or decreases during lactation (6) Postprandial thermogenesis during lactation was found to be reduced by 30% in one study, but the overall impact of the reduction was small, since postprandial thermogenesis represents only about 10% of total energy expenditure. The final area where energy could be spared is physical activity, and the potential savings are entirely dependent on the habitual level of activity during the nonpregnant state (8). Activity levels of lactating mothers may be decreased if they remain housebound but previously worked and exercised regularly, or may be increased if they exercise regularly during the postpartum

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period but were previously sedentary. Reduction in activity has the potential to spare energy to support lactation, but the absolute savings are likely to be small (6) compared with the contribution of energy intake.

Healthy lactating women in developed countries typically lose 0.5 to 1.0 kg per month, on average, and milk volume is not related to maternal weight or height or indices of body fat (8). In developing countries, evidence is conflicting about whether thin women produce less milk than do women with higher weight-for-height. Increased maternal energy intake has not been linked with increased milk production, at least among well-nourished women in industrialized countries. Nutritional supplementation of lactating women in developing countries where undernutrition may be a problem has generally been reported to have little or no impact on milk volume, but most studies have been too small to test the hypothesis adequately (8).

Not all lactating women lose weight postpartum (8-10); for example, in the study of Manning-Dalton and Allen (9), 22% actually gained weight during breastfeeding. Studies examining the role of parity on weight retention have shown that, overall, each pregnancy adds 0.4 to 2.4 kg to body weight (after controlling for age) (11-21), but for some individuals the weight gain is considerably greater (15,21-22).

In summary, it is clear that the widely held assumption that human lactation is naturally associated with rapid catabolism of fat stores is not substantiated by the literature. Furthermore, as discussed below, the question as to whether women who lactate lose the weight gained during pregnancy faster than their nonlactating counterparts is not yet fully answered. For some women, pregnancy, whether lactating or not, may be associated with considerable weight retention. Interestingly, the advice that women who are planning to breastfeed or are breastfeeding receive from health professionals regarding this subject has not been well documented. Most perinatal texts claim that women will return to their prepregnant weight between 6 weeks and 6 months after delivery (23-25). Some widely accessible lay books state that women will regain their prepregnancy figure faster if they breastfeed (26,27). It is important that women be given realistic, healthpromoting advice about weight change during lactation.

The primary objective of this study is to compare the patterns of weight change in a well-nourished, mixed-race, multi-ethnic population in Montreal according to type of infant feeding method used during the first 9 months postpartum. The principle research questions are:

(1) In a well nourished population, are there any important differences in the rate of postpartum weight loss in the first 9 months postpartum according to the extent of lactation?

(2) Does the effect of lactation on weight loss vary according to maternal prepregnancy body in mass index (BMI) and/or weight gain during pregnancy?

2. LITERATURE REVIEW

2.1 THE EFFECT OF LACTATION ON POSTPARTUM WEIGHT CHANGE

Two types of studies have examined the relationship between type of infant feeding and postpartum weight loss in well-nourished women: 1) small-scale nutritional studies with short periods of follow-up designed primarily to study the energy cost of human lactation and 2) larger-scale epidemiologic studies with longer periods of follow-up designed to explore the relationship between pregnancy/parity and the development of obesity.

2.1.1 Small-scale nutritional studies

Table 1 summarizes the available data from the studies on the rate of postpartum weight loss in well-nourished lactating and nonlactating women.

<u>**TABLE 1</u>** - Postpartum weight change in well-nourished lactating and nonlactating women</u>

SOURCE	LACTATING	NONLACTATING	FOLLOW-UP
(Reference), country, year	Weight change kg/month (n)	Weight change kg/month (n)	Weeks at initial, last weight
(28) Australia, 1968	- 0.3 (16)	- 0.4 (10)	6-8, 25
(4) UK, 1970	- 1.2 (23)	- 1.1 (32)	1, 8 (6-17)
(29) UK, 1975	- 1.0 (22)	- 1.1 (20)	1.5, 12
	- 0.5 (22)	- 0.8 (20)	1.5, 25
(30) UK, 1981	- 0.6 (25)	-	2, 16
(9) USA, 1983	- 0.7 (12)	- 1.2 (6)	2, 13
(10) USA, 1984	- 1.3 (45)	-	1-3 days, 16
	- 0.5 (45)	-	4, 16
(31) USA, 1986	- 1.1 (22)	-	weekly rate 6-24
(32) Sweden, 1988	- 1.8 (23)	-	5-10 days, 8
	- 0.8 (23)	-	5-10 days, 25
(33) USA, 1990	- 0.3 (46)	- 0.3 (41)	4, 12
	- 0.8 (46)	- 0.4 (41)	12, 25
(34) USA, 1989	- 2.3 (21)	- 2.7 (15)	1-2 days, 13
	- 0.4 (21)	- 0.1 (15)	13, 25
(35) Netherlands, 1991	+ 0.2 (40)	+ 0.2 (16)	5, 9
	- 0.2 (16)	-	5, 56
(36) USA, 1993	- 2.7 (7)	- 2.9 (5)	1-3 days, 13
	- 0.4 (7)	- 0.3 (5)	13, 25

Differences in timing and duration of the studies, as well as in prepregnant weight and gestational weight gain, prevent the calculation of an average rate of weight loss for each group of lactating and nonlactating women. Nevertheless, the rate of weight change generally seems to be small in both lactating and nonlactating women, ranging overall from -2.9 to +0 2 kg/month, with no particular trend over time for those with comparable follow-up periods. The wide range of reported values may be attributable to differences in baseline weight measurements (8), duration of follow-up, or small sample sizes (i.e., sampling variation). Higher rates of weight loss are consistently found in those studies where the initial weight is measured within days of birth and the period of follow-up is shon (3 months or less). These higher rates represent in part the rapid urinary loss of fluid that occurs during the first days after delivery (postpartum diuresis). The rate at which a woman (lactating or not) returns to her prepregnancy weight after delivery is affected by many factors: edema during pregnancy, the route of delivery, prepregnancy weight, gestational weight gain, postpartum weight, parity, maternal age (8), pregnancy and postpartum smoking (37) and physical activity postpartum (9).

Overall, the rate of weight loss during the first 3-4 months postpartum seems to be no greater for lactating than for nonlactating women. This finding may partly be due to the fact that nonlactating women choose voluntarily to restrict their caloric intake after delivery more often than lactating woman $(29,3^4,38)$; it would be interesting (albeit difficult methodologically) to compare rates of weight change in lactating and nonlactating women with both groups eating ad libitum. Two recent studies with longer follow-up periods reported that weight loss from 3 to 6 months was greater for lactating than for nonlactating women, suggesting that lactation may speed weight loss if prolonged (33,34).

In these nutritional studies, the samples sizes have been generally small, particularly considering the high variability of postpartum weight change. Since most of the studies were designed to address the more basic question of the energy cost of lactation and its impact on body weight and composition, they required labour-intensive data collection procedures that would be difficult to apply in large-scale epidemiological studies. Another difficulty in comparing studies is the difference in their definitions of "lactating" or "nonlactating" and their failure to consider the extent of supplementation of infants with solid foods. For example, some researchers considered women to be nonlactating if they were not exclusively breastfeeding (i.e., if they were using either mixed feeding or exclusive bottlefeeding) (9,33) whereas others considered women to be nonlacating only if they were exclusively bottlefeeding (34,36); thus, different degrees of lactation: *i* ave been examined in different studies.

Earlier studies in this area have failed to adequately describe their study subjects, although the groups studied showed small variability in body weight (4,28-29). Similarly, there is very little information about techniques for ascertaining anthropometric measures or potential confounding factors.

As to more recent studies, Manning-Dalton and Allen reported on 27 wellnourished primarily breastfeeding (either exclusively or not) primiparae followed from day 12 to day 90 postdelivery (9). The average net pregnancy weight gain at day 12 was 6.0 \pm 4.0 kg (mean \pm standard deviation), ranging from -0.5 to 15.4 kg. The average weight loss between day 12 and 90 postdelivery was lower in those mothers exclusively breastfeeding (average weight loss: 1.7 ± 2.7 kg) than in those supplementing their infant with formula for 50% of their energy intake or more (3.1 \pm 1.9 kg).

Butte et al. followed 45 exclusively breast-feeding, nonsmoking, primi- and secundiparae from immediately postdelivery (1-3 days) to 4 months postpartum. After excluding the first month (where the average weight loss was 3.3 kg), they reported an average rate of weight loss of 0.5 kg/month with a considerable range of weight change: - 5.6 to +5.5 kg/month (10). This average rate of weight loss is similar to the rates observed in two other studies with a similar follow-up period (30,33).

Heinig et al. reported (abstract only) that there were no significant differences in the amount of weight loss from 1-3 month postpartum (average 1.0 ± 2.0 kg) between 46 women who exclusively breastfed (as the sole source of milk) for at least 12 months and 41 women who did not breastfeed for more than 3 months, even when women who breastfed for 1 month or more were excluded from the latter group. However, weight loss from 3-6 months postpartum was significantly greater in the exclusively breastfeeding group than in the bottlefeeding/mixed feeding group (2.4 ± 2.1 kg vs 1.3 ± 2.6 kg) even after controlling for maternal dieting, percent ideal body weight and gestational weight gain (33).

Brewer et al. recruited 56 well-educated, middle- to upper-middle-class, mostly white pregnant women and followed them until the 6th month postdelivery. Anthropometric measurements were taken immediately after birth (1-2 days) and at 3 and 6 months. They compared anthropometric changes in three feeding groups: exclusively breastfeeding (BF), exclusively formula feeding (FF) and combination feeding (CF). All of the groups experienced significant weight loss with small within-group variability during the first 3 months, but there were no significant differences in weight loss among the 3 groups during this period [6.75 \pm 0.53 kg (BF), 8.14 \pm 0.68 kg (FF), 6.39 \pm 0.53 kg (CF)]. Between 3 and 6 months only, the exclusively breastfeeding group showed a significantly greater weight loss compared with the exclusively formula feeding and the combination feeding groups $[1.29 \pm 0.64 \text{ kg} (BF), 0.16 \pm 0.85 \text{ kg} (FF), 0.82 \pm 0.65 \text{ kg}$ (CF)](34). In a recent study, Kramer et al. (36) followed 24 women from the time of their delivery until 6 months postdelivery. Anthropometric measures were taken immediately after birth and at 1, 3 and 6 months. The change in body weight was compared in three feeding groups: exclusively breastfeeding for the entire 6 months (N=7), exclusively bottlefeeding (N=5) and combined breast and bottlefeeding (N=12). The rates of weight change in the first three months postpartum were similar to those reported by Brewer et al. but much higher than those found in other studies (see Table 1). The high rates of weight loss in these two studies may be explained by: 1) the initial weights at 1-3 days postdelivery include fluid that is rapidly lost during the first days postpartum and 2) the

average gestational weight gains were higher [15.2 (34) and 17.5 (36)] than in other studies. In a repeated measures analysis of covariance, Kramer et al. found no significant change in weight over time between the three feeding groups even after adjusting for gestational weight gain. The feeding method by time interaction was significant when the breast- and combined feeding groups were collapsed and compared with the formula feeding group; women in the breast- and combined feeding groups lost weight faster only during the first month than women in the formula feeding group (36). This modifying effect of time may represent fluctuations in postpartum diuresis, rather than a true effect of lactation on body stores. Even though this study used adequate measurement techniques for both anthropometry and feeding variables and an appropriate strategy for the statistical analysis, it had the dual disadvantages of a very small number of women per feeding category and a very large attrition rate (60%).

Two other studies had the advantage that women were followed from the preconception period or early gestation, so that valid baseline measures of body weight were available for comparisons with those in the postpartum period. Sadurskis et al. reported on 23 educated matried breastfeeding primi- and multiparae followed from the prepregnant period into their pregnancy and postpartum. They found that the amount of weight remaining over prepregnancy weight was very variable: 2.9 ± 2.7 kg at 2 months: and 1.5 ± 3.1 kg at 6 months postpartum. Between 5-10 days and 2 months postparturn an average of 2.6 kg of weight was lost (32), van Raaij et al. followed 40 breastfeeding women and 16 women who had exclusively bottlefed or had breastfed for less than 3 weeks, from the 12th week gestation to the 9th week postdelivery. The amount of weight remaining over the weight at 12 weeks of gestation was also very variable: 1.8 kg \pm 2.9 kg and 1.6 \pm 3.0 kg at the 5th week postpartum for the breastfeeding and bottlefeeding groups respectively. Between the 5th and 9th week, the body weight increased slightly for both groups. A subgroup of 16 breastfeeding women (whose average body weights at 12 weeks gestation were higher than the group as a whole) followed for over a year showed a decrease of body weight of 2.3 ± 3.6 kg between weeks 5 and 56 postdelivery (35).

Several methodologic problems arise from the more recent studies, though some of these issues apply to earlier studies as well. In some of the studies, the subjects involved were predominantly breastfeeding, and no comparison groups were studied. Only four studies (9,34-36) compared exclusively breastfeeding women with those exclusively or almost exclusively bottlefeeding, and definitions of these feeding groups varied from study to study. All studies used volunteer subjects restricted to middle and upper socioeconomic status (SES), homogeneous groups with less risk for confounding by sociodemographic characteristics but with reduced generalizability of the results.

Overall, the measurement techniques were adequate, particularly for those involving measures of body weight and energy intake, whereas the measurement techniques to monitor the extent of lactation and supplemental feedings were not always specified. With respect to the statistical analysis, despite collecting data over time, there was no attempt (with the exception of Kramer et al. (36)) to use all the data points instead of taking an average measure (i.e., rate of overall weight change) or fractioning the follow-up period (i.e., 1-3 months, 3-6 months, etc.). This type of data renders itself to repeated measures analysis, whereby all data available for each individual are used, allowing greater efficiency (power) for detecting significant differences between feeding groups in the main variable of interest. Also, the sample sizes in these studies were generally small, which in view of the high variability of postpartum weight change, provided low statistical power to detect a difference in weight change between feeding groups.

Lastly, it should be noted that the length of follow-up is crucial in these studies and also affect the generalizability of results. Studies with follow-ups of 3 months or less (23) may be too short to adequately describe the effect of lactation on body energy stores. Sadurskis and van Raaij found that in lactating women there was no body fat loss in the first 2-3 months after delivery and that mobilization of fat tissue occurred only between the second or third and the sixth month postpartum (32,35). Butte et al. reported that, after excluding the first month postpartum, the highest monthly rate of weight change occurred between the third and the fourth month (10). Brewer et al. report that significant fat loss (as measured by sum of skinfold measurements) during the first 3 months postpartum occurred only in the exclusively bottlefed group, whereas the exclusively breastfed and the mixed feeding groups experienced a significant decrease between 3 and 6 months (34). Thus the effect of feeding type may differ by period, even within the first 6 months postpartum.

2.1.2 Large-scale epidemiological studies

The second group of studies addressing the relationship between type of infant feeding and postpartum weight change were primarily designed to explore the association between pregnancy/parity and obesity in developed countries and to examine long-term changes in body weight following lactation. Overall, it has been shown that each pregnancy adds 0.4 to 2.4 kg to body weight (after controlling for age) (11-21), but for some individuals the weight gain is considerably greater (15,21-22).

Some of these studies have examined the modifying effect of mode of infant feeding on the pregnancy/body weight relationship. Two large longitudinal studies have reported on weight change after pregnancy and analyzed the possible effect of lactation. In the late 40's, McKeown and Record reported a small but consistent difference in body weight in 694 women lactating for different lengths of time (<3, 3-6 and >6 months of exclusive breastfeeding). Women who breastfed for longer periods lost on average more weight between 3 and 12 months postpartum, and these relationship did not seem to be confounded by age. The variations in weight according to duration of lactation were almost eliminated by 24 months after delivery (13). Unfortunately, the group that breastfed for more than 6 months was quite small (n=37), and information on the extent of lactation when not exclusive was not available. Öhlin and Rössner followed 1423 Swedish women from the first prenatal visit to 1 year postpartum to assess predictors of weight retention. After controlling for confounders, a lactation score (4 points for every month of full lactation and 2 points for every month of mixed feeding) had a weakly

negative (although statistically significant) association with weight retained at 1 year postdelivery above the self-reported prepregnancy weight (β =-0.04, p<0.001). The lactation score explained only 0.9% of the variance in postpartum weight change, whereas gestational weight gain explained 12.7%; where the higher the gestational weight gain, the higher the weight retained at 1 year postdelivery. Larger degrees of lactation seemed to have the largest effect on weight loss between 2.5 and 6 months postpartum, but by 12 months postpartum the total amount of weight loss did not differ significantly by lactation score. Two strengths of this report are the large sample size and the attempt to better quantitate duration and the intensity of breastfeeding by means of a score (21).

In another longitudinal study, Rookus et al. compared the change in body mass index from pregestation through 9 months postpartum of 49 pregnant women with the corresponding change in 400 non-pregnant women. They report that, after adjusting for confounders, there was no difference in the change of body mass between the two groups; at 9 months postpartum the total group of pregnant women had gained as much body mass as was expected by aging. On the other hand, the authors found that breastfeeding practices modified the effect of pregnancy on body mass index even after adjusting for confounders; women who breastfed for more than 2 months gained more body mass than their non-pregnant counterparts (12). Unfortunately, the subgroup of women breastfeeding for longer than 2 months was very small (n=18), and despite the long follow-up, no information was provided beyond 2 months regarding the extent and duration of lactation.

In a cross-sectional study of 35,556 women, Newcombe found that type of infant feeding was an effect modifier of the parity/body weight relationship. The effect of parity on body weight at 20 weeks of gestation of the index pregnancy was almost one third larger in those who had breastfed than in those who had formula fed their infants after previous pregnancies (14). One clear advantage of this study was the very large sample, but a serious limitation was that the duration and extent of breastfeeding used after the index pregnancy were not defined and, more importantly, it was assumed that the method of feeding used after previous pregnancies was the same method used after the index pregnancy. Also, the pregnancies of the same women were unjustifiably treated as independent units in the analysis (8).

Several key confounders of the infant feeding/postpartum weight change relationship have been reported in the above-cited literature. Gestational weight gain has consistently been found to be a predictor of weight change [i.e., the greater the gestational weight gain, the greater the postpartum weight loss(9,35)] and a confounder of the relationship of interest (33,35-36). The role of prepregnancy BMI or percent ideal body weight-for-height as a confounder is less clear. Two studies (9,33) adjusted for its potentially confounding effect by means of multivariate analysis; one found that women with greater prepregnancy percent ideal weight-for-height tended to lose more weight postpartum (9), whereas the other reported the opposite finding (35). Another large study did not find prepregnancy body mass index to be a significant predictor of weight retained one year after birth (21). This latter study showed that initially overweight women have a more variable postpartum weight change than leaner women, but differences in the degree of lactation did not explain why some overweight women lost more weight than others (55). Age was an important covariate in the studies examining the relationship between pregnancy/parity and weight retention (12,15,21). Postpartum physical activity was measured in at least two studies; one found a significant association between physical activity and weight change (but did not report its relationship to the method of infant feeding nor test its role as a confounder in the multivariate analysis) (9), but the other did not (35).

The only factor examined as a modifier of the effect of infant feeding on postpartum weight change association was time, i.e. to explore whether the effect of lactation on weight change varied over time. As mentioned above, Kramer et al. reported a significant method of infant feeding by time interaction (36), but since the effect was observed only during the first month postpartum, it is more likely to represent, if anything, a differential effect of lactation on extracellular fluid fluctuations than on body fat stores. A study conducted on a large group of urban Filipino women followed for 2 years found that any lactation during the 2-year follow-up period of full lactation during the first 6 months postpartum had a significant negative effect on weight and that this effect significantly increased over time (39). It should be noted that although this study was methodologically sound, the generalizability of it's results to a developed country setting remains unclear.

In conclusion, the literature reviewed in this section on the relationship between type of infant feeding and postpartum weight loss suggests the following for wellnourished women in developed countries:

1) in the first 3 months postpartum, no clear difference in the rate of weight loss is apparent between lactating and nonlactating women.

2) Between 3 and 6 months postpartum, women lactating for longer periods and more intensively (i.e., 5-6 months of exclusive or nearly exclusive breastfeeding) may show a greater rate of weight loss than women exclusively bottlefeeding or those lactating less fully or for a shorter duration (i.e., less than 3 months of exclusive breastfeeding) (13,21,33-34).

3) By 1-2 years after pregnancy, no clinically significant relationship is evident between the duration and intensity of lactation and weight retained above prepregnancy weight (13,21).

2.2 THE CONTRIBUTION OF FAT STORES AND ENERGY INTAKE TO THE COST OF LACTATION

Studies on body composition have examined the actual contribution of maternal fat stores to the cost of lactation. Irrespective of the methodologic approach, both Manning-Dalton and Allen (9) and Butte et al.(10) estimated that the energy mobilized from the tissues between 15-30 days to 3-4 months was 115-165 kcal/day This energy deficit is markedly less than the 200 to 300 kcal/day assumed in the calculation of the recommended daily allowances (RDA) for lactation (23,40). The remainder of the energy needs derive from the diet and from energy-sparing adaptations, such as reduced activity and thermogenesis. Interestingly, these two studies reached similar conclusions regarding the role of energy intake in lactation. Manning-Dalton and Allen reported that the effect of lactation during the first 3 months postpartum on weight change was small, and that most of the "explainable" difference in weight change was accounted for by differences in energy intake (9). Butte et al. concluded that milk production is not dependent on the amount of tissue reserves but on the energy intake; i.e. although mothers whose body fat content was less than 20% did not produce less milk, they did consume more energy (9,10). Also, more obese women and those who gained more weight during pregnancy lost more weight but also consumed fewer calories on average (2,9). Obviously, energy intake (and expenditure) plays a crucial role in the relationship between lactation and weight change and probably lies on the casual pathway of this relationship Rosso has proposed that, although the exact mechanisms involved are not known, the main determinant of the "physiological hyperphagia" observed during lactation seems to be the nutrient drain imposed by milk production. In contrast to pregnancy, hormones do not appear to play a significant role (41).

Many other investigators have actually attempted to document the increased energy intake of well-nourished lactating women. Studies from the UK and Australia during the early 1970's (4,28-29) consistently found higher mean energy intakes in lactating women (2500-3000 kcal/day) than more recent studies (2000-2300 kcal/day) (9-

10,30-31,35,42-43). This would be consistent with an already documented secular trend towards a decline in energy consumption over the past 10 years or so in the UK (6,38); this trend, however, has not been documented in pregnant women (38,44). In fact, gestational weight gains have been increasing over time (11).

Almost all published studies agree that the mean energy intake of lactating women is higher than that of nonlactating, nonpregnant women (4,9,28-30,32,34-35,42-43,45). Although accurate dietary intake data are notoriously difficult to obtain and may systematically underestimate true intake, the consistency of the results across studies from different countries using different data collection methods is reassuring. On the other hand, very few studies have made longitudinal measurements of food intake in wellnourished lactating women and have included either prepregnant or post-weaning reference measurements (6). Black, Wiles and Paul (45) reported an average increment of 490 kcal/day in months 2-4 of full lactation compared with measurements made 3-6 months post-weaning in 56 women in the UK. Sadurskis and van Raaij reported an average increment of 260-290 kcal/day at 2 months postpartum of full lactation compared with measurements made before and early in pregnancy. (32,35).

But the majority of the scientific evidence concerning differences in energy intake come from studies that compare mean intakes from different groups of lactating and nonpregnant, nonlactating women. In a review of articles published after 1970, comprising 13 studies of lactating women and 9 studies of nonlactating women, mean intakes were 2350 kcal/day and 1920 kcal/day respectively (6). The difference (430 kcal/day) is very close to the revised 1985 WHO/FAO/UNU recommended increment of 500 kcal/day (23). But, despite attaining good lactational performance, the absolute intake of 2350 kcal/day is well below the recommended intake of 2700 kcal/day for women with light activity patterns (8).

2.3 ATTITUDES AND BELIEFS TOWARDS POSTPARTUM WEIGHT CHANGE

Attitudes and beliefs towards postpartum weight change have not been extensively explored either among mothers or health professionals. Most nursing and nutrition textbooks claim that the women will return to their prepregnant weight between 6 weeks to 6 months after delivery (23-25). Some widely accessible lay books state that women will re-gain their prepregnancy figure faster if they breastfeed (26,27). An information pamphlet from La Leche League advises women that slow weight loss is compatible with lactation. It also states that breastfeeding will help mothers lose the extra fat deposited during pregnancy as an energy reserve to subsidize the cost of lactation, whereas those mothers who bottlefeed must rely on dieting and exercising to lose weight postpartum (46). A Mohawk College information booklet states that breastfeeding will help mothers lose about 1 to 2 pounds each month in the first 4 to 6 months postpartum (47). Olsen and Hundt postulate that weight loss during the puerperium is probably of much concern to the mothers (48), but the knowledge women have or the advice they receive with respect to anticipated weight change is not well documented.

Dusdieker et al. used multivariate techniques to identify primary and secondary (indirect) predictors of the choice of infant feeding method in 100 exclusively breastfeeding and 57 bottlefeeding primigravida (49). These women were given a questionnaire developed earlier by the same investigators (50) that measured attitudes and perceptions important in the choice of feeding method. Women were asked to quantitate the influence of a series of items on their decision to breastfeed or not. The study findings agree with those of many other studies (51-56) insofar as infant-centered beliefs about breastfeeding (items: "best for baby", convenient) were found to be pivotal in determining whether a mother will breastfeed or not. Interestingly, the strongest net predictor of maternal breastfeeding beliefs was the mother's expectation that she would herself benefit from breastfeeding (items: the desire to be a "complete" woman, enjoying the sensation of breastfeeding, feeling that breastfeeding will help regain her figure). Hence, a woman's anticipation that her own needs will be satisfied by breastfeeding acts indirectly to strengthen and reinforce her convictions that breastfeeding will benefit her child (49). These findings seem to indicate that the mother-centered beliefs play a crucial role in the decision to breastfeed, and it could be postulated that these beliefs may also contribute somehow to determine the duration of breastfeeding. Similarly, Manning-Dalton and Allen speculate that, in our weight-conscious society, women may make the decision to breastfeed in the hope of losing weight. They further postulate that if greater weight loss does not occur as fast as expected, these women may become frustrated, perhaps leading to adverse emotional consequences for both the mother and her child. If this happens, women may be more likely to restrict food intake (9). This would not be surprising, since several authors have reported that many lactating women consciously diet (38,43,55). In one study, short-term energy restriction to levels below approximately 1500 kcal/day led to a considerable reduction in milk production (31); if prolonged, such energy restriction could possibly lead to cessation of breastfeeding.

In conclusion, it is likely that maternal attitudes play a key role in the success of lactational performance. If women could be given appropriate advice on the most likely rate of weight loss and the effects of different degrees and durations of breastfeeding, these negative consequences of excessive energy restriction might be avoided and the duration of breastfeeding thereby prolonged.

2.4 GAPS IN EXISTING KNOWLEDGE

The literature reviewed above reveals several important gaps in the existing knowledge regarding the relationship between infant feeding and postpartum weight change:

- The definition of feeding groups (i.e., criteria for breast-, mixed- and bottlefeeding) is neither clear nor uniform across studies. Few studies have accounted for both the intensity and duration of lactation when defining infant feeding practices. Moreover, the extent of supplementation with solids and juices has not been considered in these definitions. This imprecision may well have resulted in considerable misclassification of the exposure variable. The World Health Organization (57) has established criteria for the inclusion of infants in feeding categories. These criteria are:

- Exclusive breastfeeding: requires that the infant receive only breastmilk^a; allows the infant to receive only drops or syrups^b.

Predominant breastfeeding: requires the infant to receive breastmilk^a as the predominant source of nourishment; allows the infant to receive only liquids (water and water-based drinks, fruit juice, ORS), ritual fluids and drops or syrups^b.
Complementary feeding: requires the infant to receive breast milk and solid or semisolids foods; allows the infant to receive any food or liquid including non-human milk.

- Breastfeeding: requires the infant to receive breast milk; allows the infant to receive any food or liquid including non-human milk.

- Bottlefeeding: requires the infant to receive any liquid or semi-solid food from a bottle with nipple/teat; allows the infant to receive any food or liquid including non-human milk and also allows breast milk by bottle.

* Includes milk expressed or from wet nurse.

^b Vitamins, minerals and medicines.

- The effect of prolonged (i.e., more than 6 months) exclusive or full breastfeeding on body weight has not been thoroughly examined.

- Many women, whether lactating or not, seem to diet in the postpartum period. The average rate of weight loss of either group eating ad libitum is not known. For those women planning to diet during lactation, prolonged periods of energy restriction has uncertain effects on milk volume and nutrient stores. The threshold below which energy intake is insufficient to support adequate milk production has not been determined.

- It is not known if women who breastfeed experience faster rates of weight loss after cessation of breastfeeding than women who do not breastfeed at all.

- With respect to the statistical analysis, despite collecting data over time, there was no attempt (with the exception of one study (36)) to use all the data points instead of taking an average measure (i.e., rate of overall weight change) or fractioning the follow-up period (i e., 1-3 months, 3-6 months, etc.). This type of data renders itself to repeated measures analysis, whereby all data available for each individual are used, allowing greater efficiency (power) for detecting significant differences between feeding groups in the main variable of interest.

- Not all studies controlled for potentially important confounders such as postpartum smoking. Also, gestational weight gain is clearly an important predictor of postpartum weight change; its role as a confounder of the infant feeding/postpartum weight change relationship has not been examined.

- The roles of prepregnancy BMI and gestational weight gain as effect modifiers of the infant feeding/postpartum weight change relationship have not been examined. The only factor examined so far as a modifier of the effect of infant feeding on postpartum weight change was time (i.e., whether the effect of lactation on weight change varied over time). - It is not clear if the relationship between time and rate of weight change is linear or

polynomial.

- Mothers' and health professionals' attitudes and beliefs towards postpartum change have not been thoroughly examined. Also, the knowledge that women have and the advice that they receive have not been documented.

- The consequences of lactation for long-term maternal energy balance are unclear (8). In particular, data are insufficient to determine whether lactation influences the risk of adult-onset obesity.

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3. METHODS

3.1 RESEARCH DESIGN

Study participants consisted of women who consulted the CLSC (Centre local des services communautaires) Côte des Neiges located in the city of Montreal, province of Quebec, Canada. The CLSC serves a urban population of approximately 120,000 inhabitants in the areas of Côte des Neiges, Snowdown, Outremont and Town of Mount Royal, through its two service points: Côte des Neiges and Outremont. The community is characterized by its multi-ethnicity, especially in the areas of Côte des Neiges and Snowdown, and a high rate of families with single parents (58).

The CLSC provides pre- and postnatal services to all women living within the area of coverage. These services include a postnatal visit between the 2nd and 6th week postpartum, the exact timing depending mostly on the risk status of the new mother or family. During the visit, a detailed questionnaire is administered by the CLSC nurses to enquire about the mother's sociodemographic characteristics and her medical and obstetrical history. One copy of the questionnaire, which is called "Culture et Grossesse", is incorporated into the mother's chart, and another one is sent to the Public Health Department of Ste-Justine Hospital, where the pooled data from all the CLSCs in the territory are analyzed. The CLSC also provides preventive care for the infants in its immunization clinics. These clinics function several times a week and are run by a physician and a group of nurses.

The CLSC, then, provided an acceptable setting for a prospective study on the health of the new mothers. The main advantage of this setting was that a large group of new mothers attended the CLSC to vaccinate their infants on several occasions during the first 6-7 months postpartum, whereas they routinely attend only a single obstetric clinic or doctor's office visit in the postpartum period at around 6 weeks postdelivery. The

CLSC provided the possibility to enroll and follow new mothers for a length of time sufficient to adequately describe the effect of lactation on body weight. The main disadvantage of this setting was that no early baseline postdelivery weight was available, since the first CLSC visit is usually at 2 months postdelivery. To obtain this early measure, either immediately postdelivery or at the 6-week postpartum visit, was not feasible, since women attending the CLSC delivered their babies in different hospitals and consulted a large number of doctors for the routine 6 week postpartum visit. A research protocol was presented to the CLSC medical director in the autumn of 1989 and was reviewed and accepted by a committee formed for that purpose.

From November 1989 to July 1990, study participants were recruited into the study during their visit to the CLSC Côte des Neiges or CLSC Outremont immunization clinics (or, very occasionally, medical clinics) only if they had a baby was 8 months of age or younger. The recruitment was carried out by the CLSC nurses or by two of the investigators conducting the study (L.N.H., R.T.).¹ The mothers were given a brief explanation of the study by the health professionals (without revealing the study hypothesis), together with an information pamphlet. If the mother agreed to participate, she was weighed and measured. The information was recorded in a specially designed form included in the baby's chart. The newly recruited subjects were identified, the medical record, and a list containing the names and telephone and medical record numbers of mothers and babies was given as soon as possible to the investigators. Thereafter, the participants were contacted by telephone by one of the investigators, who then administered the "initial" study questionnaire. This questionnaire included a verbal consent to participate and questions about method of infant feeding and maternal work, exercise, diet and smoking practices since the baby's birth. Since both interviewers were trilingual (English, French and Spanish), few cases needing an interpreter were

¹ Rossana Tirado (R.T.) participated in the design and initial collection of the data as part of a required Family Medicine residency research project.

encountered.²

After a mother was recruited, her chart (if available at the CLSC) was scanned to verify if the Culture and Grossesse questionnaire was present. If so, the baseline sociodemographic and obstetrical characteristics were extracted from the chart. If there was no Culture and Grossesse questionnaire available or if it was incomplete, the required information was collected by telephone.

Women were eligible to participate if their baby was 8 months of age or younger, the gestation had been single and the birthweight of the infant had been 2000 grams or more. The only exclusion criteria were a life-threatening illness of the mother and/or infant or a repeat pregnancy at the time of the recruitment.

If the first encounter with a participant was at the time of her infant's 3rd DTP/polio vaccination (around 6-7 months of age), this usually represented the only contact with the subject at the CLSC. For women recruited at the time of their infants' 2nd DTP/polio vaccination or earlier, a weight was taken (whenever possible) at all subsequent visits to the CLSC until no later than th \ge 9th month postpartum.³ For some of these women, the weight at recruitment was the only one available, whereas for others, further weights were recorded after recruitment up to the 3rd DTP/polio vaccination. Other women had a weight recorded at the 1st and 2nd DPT/polio vaccination but not at the 3rd, resulting in a overall follow-up period of approximately 4-5 months instead of 6-7 months. After each visit, medical records personnel at the CLSC identified the chart and handed the list of names and telephone numbers to the investigators. Thereafter, each participant was contacted by telephone and the "follow-up" study questionnaire was administered. This questionnaire included information on type of infant feeding and

² Most of the telephone interviews were carried out by the principal investigator (LNH), except for a period of a few months, when two research assistants provided additional help.

³ Only eight women had their last weight taken in the 9th postpartum month (243 to 273 days).

maternal work, exercise, diet and smoking practices from the time of the previous visit to the present one. If a woman became pregnant again during the follow-up period, only the weights obtained before becoming pregnant were retained.

FIGURE 1. Schematic presentation of the research design



Inherent to this design is that study women participated during different periods postpartum, for different lengths of time and with a different numbers of contacts and intervals between contacts. With respect to the terminology used below, the overall "follow-up" period is considered as the time between the delivery and the last CLSC visit and an "interval" is defined as the time between the delivery and the first CLSC visit or between any two consecutive CLSC visits. For example, a subject with two visits to the CLSC would have three data points (delivery, first visit and second visit), the overall follow-up period would be the time between the delivery and the second visit, and the two intervals would be the time between the delivery and the first CLSC visit and the time between the first and second visits.

3.2 MEASUREMENT TECHNIQUES

3.2.1 Study sample baseline characteristics

The following sociodemographic and obstetrical characteristics were recorded:

SOCIOECONOMIC STATUS VARIABLES	OBSTETRIC VARIABLES	
Age of mother at delivery	Prepregnancy weight	
Completed years of education	Height	
Marital status	Gestational weight gain ^a	
Living situation (with or without a partner)	Parity	
Birthplace of mother and father	Duration of pregnancy ⁴	
Years since arrival in Canada	Place and type of delivery	
Source of income	Postpartum complications	
	Referral to Montreal Diet Dispensary	
	Smoking during pregnancy	
	Infant's sex, birthweight, and	
	admission to a Neonatal Intensive	
	Care Unit	

*Self-reported

This information was collected at different times; some women reported it when completing the Culture et Grossesse questionnaire at 2-6 weeks postdelivery, whereas others provided it only after recruitment to the study. This is less of a problem for stable socioeconomic characteristics and clinical attributes but might have been important in the reporting of the prepregnancy weight, gestational weight gain and other obstetric variables, for which a longer time had elapsed from delivery and accurate recall may have been more difficult. Also, other measurement errors are expected both in self-reported prepregnancy weight and gestational weight gain, because of rounding (e.g., to the nearest 5 or 10 pounds) and the well-known systematic underreporting of prepregnancy weight, particularly by overweight subjects. Studies on the validity of self-reported body weights on (nonpregnant) adult populations have shown that subjects consistently underestimate body weights by an average of 1.1 kg(59) to 1.9 kg(60), that women underestimate their weights more than men (mean: 1.4 versus 0.7 kg)(59), and that the extent of this underestimation increases as actual weight increases (59) more so for women than for men (60). The magnitude of this bias seems nevertheless to be smaller for pregnant women. An analysis of a subgroup of 39 women in Ohlin and Rössner's study who conceived again during the follow-up period showed that the self-reported prepregnancy weight in the subsequent pregnancy was 0.80 kg lower than the recorded weight (21). Similarly small discrepancies were found in two other Scandinavian studies (mean underestimation of prepregnancy weight of 0.5 and 0.6 kg) (32,61). There is no evidence that this systematic underestimation of prepregnancy weights is differential with respect to type of infant feeding.

3.2.2 Type of infant feeding

Two questionnaires were developed to record methods of infant feeding: an "initial" form was administered during the first telephone contact with the mother, and a shorter "follow-up" version was used thereafter. In the initial interview, the information collected consisted of the type of feeding, by month, from birth to the time of the visit to the CLSC. Mothers were asked initially whether they were fully breastfeeding, fully

bottlefeeding or using mixed feeding. If they were both breast- and bottlefeeding, detailed information was asked on the daily quantity and size of bottles of formula being fed, on average, by month. Also, the mothers were asked whether the baby was eating foods other than milk, such as solids and juices. If solids and/or juices were taken, mothers were questioned about the age when the baby first started consuming them.

Feeding practice questionnaires were translated by the investigators into French and Spanish. Back-translation to English was performed by bilingual health professionals blinded to the original questionnaire and the study hypothesis. The original and backtranslated forms showed a few discrepancies that were corrected. Cross-language equivalence was tested by administering the translated and original forms of the questionnaire to bilingual subjects; there were no discrepancies in the answers given with either form, adding further evidence that the questions were equivalent (62).

The original and translated versions of the questionnaire were pretested by administering them to a group of 10 mothers (convenience sample) to check for comprehensibility.

In the questions assessing extent of lactation, reporting problems are most likely to occur in those mothers who do not exclusively breast- or bottlefeed, because these women were asked to report the exact number of bottles that were given to their infants per day, and detailed information of this sort may be difficult to recall. Because the categories of extent of lactation were defined based on this information, there may have been a misclassification of exposure introduced by this difficulty in reporting. This misclassification of exposure should be independent of weight change status (nondifferential), however, and thus lead, if anything, to a conservative estimate of the exposure-outcome association.

Internal consistency was carefully evaluated by examining for "inconsistencies" in the answers; the structure of the questionnaire permitted such an examination. The

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initial portion of the questionnaire asks mothers about method of feeding (milk and solids) during the present month, whereas the latter part asks mothers about feeding patterns from birth to the month prior to the interview. It follows that, for example, a mother who was breastfeeding with two regular bottles/day at two months, if consistent, should answer that she was breastfeeding, exclusively or not, at birth and at one month of age. Similar reasoning was used for data on solids. Owing to the interview nature of the personal interview, most inconsistencies were resolved during the interview.

3.2.3 Anthropometric measurements

During each visit to the CLSC, the mothers were weighed with no shoes or coat on a beam balance. Height was measured once with an upright extension meter, usually at the initial contact.

A certain amount of random error in measurement of weight and height was expected from the methods used and from the fact that there were several observers involved in the process. Also, because the weights were taken at different times of the day (9 AM to 5 PM) and weight is known to have a diurnal variation, this intraindividual temporal variation introduced another source of random error. Nevertheless, one advantage of a larger-scale study like this one is that, in the absence of bias, the average measurement of weight and height for each group should be valid even if the individual measurements from which they are derive are not.

To protect against systematically biased measurements, the scale was periodically calibrated and only one scale was used in each CLSC for most measurements. Since the women were dressed, however, all weights were slightly overestimated, and the magnitude of the overestimation changed with season. Another possible source of measurement error may have been due to the involvement of numerous observers. Nevertheless, since all observers were either nurses or physicians, a minimal standard in the measurement process was assured. Lastly, the detail of the measurement was to the nearest centimetre
for height and nearest 0.1-0.5 kg for weight (we expected some variation in detail between observers). In spite of the recognition of these sources of error, measures of weight and height are classical examples in epidemiology of "hard" data with some potential for random error but little opportunity for subjectivity.

3.3 DEFINITIONS OF VARIABLES

As explained above, the length of the overall "follow-up" period and the amount and length of the corresponding "intervals" varied for different study women. Also, many variables involved anthropometric measures and behaviors that changed during the follow-up period. Correspondingly, these variables are defined in reference to the time interval postpartum and will be referred to as "time-varying" variables, in contrast to the "nontime-varying" variables that remain constant over time. These time-varying and nontime-varying-variables are defined below.

TIME-VARYING VARIABLES:

a) Outcome variable: Average daily rate of weight change during the interval in kg/day.

This variable was computed using the weights recorded at the CLSC and a self-reported estimate of the weight after delivery. Ideally, the post-delivery weight should have been measured, but this was not possible because 1) women attending the CLSC delivered in different hospitals and were followed at the routine 6-week postpartum office visit by different physicians, making it difficult to obtain a baseline early postdelivery weight, and 2) owing to the study design, many women had delivered before the study began. To estimate this weight, we added the self-reported prepregnancy weight and gestational weight gain, and then subtracted the self-reported birthweight of the infant and an estimate of the weight of the placenta and amniotic fluid (placental weight=1/6 of baby's

birthweight, amniotic fluid weight= 1 kg).⁴ The rate of daily weight change for any given interval was then calculated as the difference between two subsequent weights divided by the number of days between weights.

b) Exposure variable: Extent of lactation during the interval.

First, an average daily intake of breast milk was calculated for each month of the followup period. For this calculation, the reported average daily formula intake in each month was subtracted from the age-specific estimate of breast milk volume available among exclusively breastfed infants from the literature (11). Second, an average daily intake of breast milk for each interval was calculated and lastly, this information was categorized into three groups:

- predominantly breastfeeding: exclusively breastfeeding or average daily intake of formula of 4 ounces or less during the interval;

- mixed feeding: average daily intake of formula of more than 4 ounces but average daily intake of breast milk of more than 4 ounces during the interval; and

- predominantly bottlefeeding: exclusively bottlefeeding or average daily intake of breast milk of 4 ounces or less during the interval.

c) Potential time-varying confounding variables:

Solids intake: Proportion of time during the interval in which solids were taken (based on when the infant first started eating solids).

Juice intake: Proportion of time during the interval in which juices were taken (based on when the infant first started drinking juices).

⁴ These estimates were suggested by Dr. Robert Usher, Chief Neonatologist, Royal Victoria Hospital.

Postpartum smoking: this variable was analyzed as continuous in the bivariate analysis (section 4.4) and as dichotomous in the multiple regression analysis (section 4.5):

- continuous: the mean number of cigarrettes smoked per day during

the interval, - dichotomous:

- no smoking during the interval
 - any smoking during the interval

Time variable: (end of the interval - beginning of the interval)/2 (i.e., number of days between birth and the midpoint of the interval comprising two consecutive weights). This measure accounts both for the differences in duration of the intervals and for timing since birth.

d) <u>Potential time-varying intervening variables</u> (variables that may lie on the casual pathway between lactation and weight loss):

Working/studying: Proportion of time during the interval in which mothers reported working and/or studying outside their homes.

Exercising: Proportion of time during the interval in which mothers reported exercising (at least once a week of any planned exercise, excluding housework).

Dieting: Proportion of time during the interval in which mothers reported dieting to lose weight.

NONTIME-VARYING VARIABLES

a) Maternal socioeconomic variables

- Continuous variables:

Age: Maternal years of age at delivery. Education: Completed years of maternal education.

- Categorical variables:

Marital status:	0 = single, widowed, separated or divorced		
	1 = married		
Living situation:	0 = lives alone or with adults other than partner		
	1 = lives with partner		
Source of income:	0 = work		
	1 = unemployment insurance		
	2 = welfare		
Birthplace:	0 = Canada/USA		
	1 = other		

b) Obstetric and infant variables

- Continuous variables:

Prepregnancy weight: self-reported weight (in kg) before becoming pregnant or at the first prenatal visit.

Height: height (in cm) at the first CLSC encounter.

Prepregnancy body mass index (BMI):prepregnancy weight/height² in kg/m²

Gestational weight gain: self-reported weight gain (in kg) from the prepregnant state (or first prenatal visit) to the end of pregnancy (usually the last prenatal visit).

Net weight (in kg) after delivery: prepregnancy weight + weight gain - birthweight - birthweight/6 - 1.

Duration of pregnancy: self-reported gestational age at delivery (in weeks). Birthweight: Infant's birthweight (in grams).

- Categorical:	
Parity:	0 = primipara
	1 = multipara
Place of delivery:	0 = Jewish General Hospital
	1 = St. Mary's Hospital
	2 = Ste. Justine Hospital
	3 = other
Type of delivery:	0 = vaginal
	1 = cesarean section
Postpartum complications ^a :	0 = none
	1 = present
Gestational smoking:	0 = no smoking
	1 = any smoking
Referral to Montreal Diet Dispensary:	0 = no
	1 = yes
Infant's sex	0 = male
	1 = female
Admission to Neonatal ICU:	0 = no
	1 = yes

* Postpartum complications were self-reported by the mother (i.e., bleeding, infection, etc.)

3.4 STRENGTHS OF THE STUDY DESIGN

Our study design attempted to address some of the existing gaps in knowledge about the relationship between breatsfeeding and postpartum weight loss (see Section 2.4). First, our sample size is larger than all nutritional studies and some of the epidemiological studies reported to date thus enhancing the statistical power to detect a difference in the rate of weight change between feeding groups. Our follow-up period was also longer than in most previous studies, which permitted a longer-term assessment of the effect of lactation on body weight.

Feeding practices were carefully measured and duration of supplementation with solids and juice was accounted for. Important potential confounders such as postpartum smoking and socioeconomic status were measured and controlled for in the analysis. The unbalanced repeated measures analysis permitted a better characterization of the effects of exposure and covariates that changed over time. We also attempted to examine the potential modifying effect of prepregnancy BMI and gestational weight gain on the of the relationship of interest.

Finally, our study design permitted an examination of the mathematical relationship between time and weight change (polynomial vs linear), as well as the possible interaction between time and feeding method.

3.5 LIMITATIONS OF THE STUDY DESIGN

Study subjects where sampled nonrandomly from a mixed-race. multi-ethnic, largely low-SES population. This may affect the external validity (i.e., generalizability) of the results. Also, the multi-ethnicity of the sample may have increased the variability of the measurements and, therefore, have reduced the statistical power to detect an exposureoutcome association.

Recruitment to the study occurred at different times postdelivery, and different women had different numbers of visits at which the measurements were obtained. This resulted in unequal follow-up periods and "missing" data points for many women, although adjustment for these time differences was attempted in the analysis. Also, no adequate baseline weight was obtained shortly after the delivery to calculate accurately the net weight retained.

3.6 ETHICS AND CONFIDENTIALITY

The procedures used in this study consisted of several anthropometric measurements and the administration of questionnaires concerning sociodemographic characteristics, obstetrical and postpartum histories and infant feeding practices. The investigators considered these procedures to present no risk of harm to the study participants. This project was approved by a research committee of the institution involved in the project, the CLSC Côte des Neiges. Although anonymity could not be offered owing to the prospective nature of the study, study subjects were assured of the confidential nature of the research process and results. All women were required to give a verbal consent in order to participate in the study.

3.7 SAMPLE SIZE DETERMINATION

For estimating the required sample size, the extent of lactation was considered as a dichotomous variable (any breastfeeding versus bottlefeeding), and the mean and standard deviation used for weight loss were those reported by Manning-Dalton and Allen: 2.0 ± 2.4 kg from 12 days to 90 days postpartum (9). Based on 80% power, a 2tailed test, and α -level of 0.05, approximately 90 women would be necessary in each group to detect a difference of 1 kg in the total amount of weight loss from delivery to a CLSC visit at 90 days.

The required sample size was recalculated once the results were available based on the observed standard deviation of 0.026 kg/day in 176 women followed from delivery to 182-243 days (6-8 months) postpartum. Based on 80% power, a 2-tailed test and α level of 0.05, 87 women would be necessary in each group (with the extent of lactation considered as a dichotomous variable) to detect a difference of 1 kg in the total amount of weight loss from delivery to a CLSC visit at 212 days (midpoint between 182 and 243 days or 6 and 8 months). This total required sample size of 174 women was very close to the initial estimate of 180 women.

3.8 STATISTICAL ANALYSIS

A descriptive analysis was carried out for all non-time-varying variables for the study sample as a whole. In order to summarize of the main variable of interest before proceeding to a repeated measures analysis, subgroup analysis was performed for three different subgroups of women followed for different lengths of time during the postpartum period. Overlapping subgroups were defined based on the following three different time periods: 1) delivery to 91-152 days (3-5 months), 2) delivery to 182-243 days (6-8 months), and 3) 91-152 to 182-243 days. For each subgroup, the outcome and exposure variable were calculated and a stratified analysis by type of infant feeding was performed.

Owing to the nature of the data set, a multivariate repeated measures analysis was performed. As a first step, bivariate associations among the variables were explored. Linear regression, t-test and Chi-square analyses were performed with SAS when assessing two nontime-varying continuous and/or categorical variables. For the portion of this analysis where at least one variable was time-dependent, a simple repeated measures analysis was performed with the BMDP program described below. Since the BMDP program does not allow a model containing a <u>categorical</u> time-varying variable or a non-time-varying variable as the dependent variable, it was impossible to examine the relationship between two of these variables.

Next, a multivariate repeated measures analysis was performed with the BMDP 5V.8 program. This program analyzes repeated measures data sets allowing for unbalanced designs (i.e., designs with missing observations) and also handles time-varying covariates (63). The regression model can be written as



$$y_{i} = \beta_{0} + \beta_{1} x_{ii} + \beta_{2} x_{2i} + \beta_{3} x_{3i} + \dots + \beta_{n} x_{ni} + \beta_{m} x_{m} + \epsilon$$

where the index *i* denotes the *i*th postpartum interval, where *n* denotes a time-varying variable, where *m* denotes a nontime-varying variable and, where ϵ represents the variability among and within subjects.

The program uses maximum likelihood approach to obtain estimates of the regression coefficients (63).

Since the maximum number of data points over time was 5 (including delivery and up to 4 postpartum CLSC visits), and the within-subject factor was "intervals" (with 4 levels), then there was a maximum of 4 repeated measurements of the dependent variable, daily rate of weight change. For a subject to be included in the analysis, it sufficed to have at least one measurement of the time-varying dependent variable not missing and none of the nontime-varying covariates missing. If a measurement of a time-varying covariate was missing, only the corresponding value of the dependent variable for that interval was treated as a missing value, (i.e., without excluding the subject entirely). Dummy variables were created to express the only time-varying categorical variable type of infant feeding (the exposure variable). A compound symmetry structure was assumed for the within-subject covariance matrix, i.e., a covariance matrix with equal diagonal elements and a constant off-diagonal. Also, the BMDP 5V.8 program assumes equal time intervals between data points. Therefore, to account for the different time intervals between visits in the present data set, a representative measure of time was included as a covariate and as an interaction term with method of infant feeding in the analysis. The measure chosen was the number of days between birth and the midpoint of the interval comprising the two consecutive weights, a measure that accounts for both the differences in duration of the intervals and timing since birth A quadratic term of this time variable was also included in the regression model to test if the relationship between time and postpartum weight change is parabolic rather than linear. Finally, postpartum weights measured within 30 days from birth were excluded from the analysis (by treating them as missing values), because the rate of weight change in the first month postdclivery is highly influenced by early postpartum fluid losses.

4. RESULTS

4.1 BASELINE CHARACTERISTICS OF THE STUDY SAMPLE

During the study period, 242 women were recruited to the study. Of these 242, 6 were excluded from the analysis either because the overall follow-up period was less than one month¹ (3 women) or because the prepregnancy weight and gestational weight gain were uncertain and we were unable to confirm them (3 women).

Table 2 describes the 236 women retained for analysis.

TABLE 2 - Baseline characteristics of the study sample.

VARIABLE (Units)

MEAN \pm SD or %

a) MATERNAL SOCIODEMOGRAPHIC CHARACTERISTICS

Age (yr)	28.5 ± 5.8
Education (yr)	13.3 ± 3.5
Marital status (% married)	69.5%
Living situation (% living with partner)	85.5%
Source of income (% work)	66.1%
(% unemployment insurance)	15.3%
(% welfare)	18.6%
Birth place (% Canadian- or US-born)	29.8%
CLSC of enrolment (% Côte des Neiges)	71.2%
(% Outremont)	28.8%

¹These women were excluded because the rate of weight change in the 1st month postdelivery 1s highly influenced by early postpartum fluid losses.

b) MATERNAL OBSTETRICAL AND INFANT CHARACTERISTICS

Parity (% primiparous)	55.1%
Prepregnancy weight	(kg)	56.4 ± 9.4
Height (cm)		158 ± 7
Prepregnancy body m	ass index (kg/m ²)	22.5 ± 3.4
Gestational weight ga	in (kg)	14.2 ± 5.0
Net weight after deliv	ery (kg)	65.7 ± 9.9
Duration of pregnancy	y (weeks)	39.4 ± 1.5
Type of delivery (% v	vaginal)	84.3%
Montreal Diet Dispen	sary (% attendance)	23.8%
Gestational smoking	(% any smoking)	9.3%
Postpartum smoking	(% any smoking)	13.4%
Place of delivery	(% Jewish General Hospital)	31.9%
	(% St. Mary's Hospital)	30.6%
	(% Ste-Justine Hospital)	18.3%
	(% other)	19.2%
Infant Sex (% female	2)	56.4%
Birthweight (kg)		$3,3 \pm 0.5$
Admission to NICU (%	% admitted)	9.3%

With respect to the method of infant feeding in the group of 236 women as a whole, 41 women never breastfed. Of the 195 women who started breastfeeding, 143 did so exclusively at birth, whereas 52 supplemented their infants with formula from birth. The mean age at introduction of juices was 76 ± 75 days and of solid food, 106 ± 45 days.

The average length of time between delivery and the last weight obtained in a CLSC visit was 189 ± 44 days. The mean \pm SD number of study visits to the CLSC at which a weight was obtained was 2.0 ± 0.8 (range 1 to 4). The distribution of the total number of CLSC study visits/participant is shown in Table 3.

TABLE 3 - Distribution of total number of CLSC study visits/participants

	Number of women	%	
1 visit	76	32.2	
2 visits	102	43.2	
3 visits	48	20.3	
4 visits	10	4.2	
TOTAL	236	99.9	

Most of the women involved in the study lost weight during the postpartum period, but a considerable number weighed more at the last CLSC visit than at delivery. For example, of the 181 women who had their last weight taken at 182 days (6 months) or later, 31 (17.1%) weighed more at the last CLSC visit than at birth (after subtracting the weights of the baby, placenta and amniotic fluid).

The women participating in this study were born in many different countries, and represented a very diverse ethnic mix. Nevertheless, for the statistical analysis, maternal birthplace was defined as a dichotomous variable (i.e., Canada/US-born versus born elsewhere) to minimize the number of terms in the multivariate model. Table 4 provides more detailed information on maternal birthplace of the study sample.

TABLE 4 - Frequency distribution of maternal birthplace

Country or region	N	%
Canada (Francophone)	47	19.9
Canada (Anglophone)	18	7.7
U.S.A.	5	2.1
South america	8	3.4
Central america	30	12.7
Caribe (excluding Haiti)	21	8.9
Haiti	11	4.7
Indoasia	27	11.4
Vietnam/Southeast Asia	10	4.2
China	4	1.7
Philippines	20	8.5
Middle east countries	5	2.1
Africa	15	6.4
Australia	1	0.4
TOTAL	236	100.0

4.2 SUMMARY MEASURES FOR THREE TIME PERIODS.

In order to give a summary of the main variables of interest, we examined the average weight change during three time periods: 1) from delivery to 91-152 days (3-5 months) postdelivery, 2) from delivery to 182-243 days (6-8 months) postdelivery, and 3) from 91-152 days to 182-243 days postdelivery. Table 5 presents the daily rate of weight change for these three subgroups.

Time period	Mean	SD	(95% C I)	Nª
Delivery to 91-152 days	-0.031	0.038	(-0.038,-0.024)	125
Delivery to 182-243 days	-0.024	0.026	(-0.028,-0.020)	176
91-152 to 182-243 days	-0.015	0.030	(-0.021,-0.009)	89
* Women may belong to more than one group				

TABLE 5 - Daily rate of weight change (in kg/day) for three time periods.

As expected, the highest rate of weight loss was observed in the period for which the baseline weight was at delivery (even after the corrections for placental and amniotic fluid weight) and the follow-up is short. Consistently, the slowest rate of weight loss is observed in the period from 3-5 months to 6-8 months postdelivery, where the large weight loss shortly after delivery has no effect.

Tables 6, 7 and 8 present the frequency distribution of the three types of infant feeding (as defined in the Methods section) over these same three time periods.

TABLE 6 - Type of infant feeding in 125 women followed from delivery to 3-5 months (91 to 152 days) postpartum.

Type of Infant Feeding	N	%
Predominantly Breastfeeding	43	34.4
Mixed Feeding	50	40.0
Predominantly Bottlefeeding	32	25.6
TOTAL:	125	100.0

TABLE 7 - Type of infant feeding in 176 women followed from delivery to 6-8 months (182 to 243 days) postpartum.

Type of Infant Feeding	N	%
Predominantly Breastfeeding	51	29.0
Mixed Feeding	76	43.2
Predominantly Bottlefeeding	49	27.8
TOTAL:	176	100.0

TABLE 8 - Type of infant feeding in 89 women followed between 3-5 months (91 to 152 days) and 6-8 months (182 to 243 days) postpartum.

Type of Infant Feeding	N	%
Predominantly Breastfeeding	21	23.6
Mixed Feeding	14	15.7
Predominantly Bottlefeeding	54	60.7
TOTAL:	89	100.0

It can be noted that women in the two time periods that include birth (Tables 6 and 7) were more likely to be predominantly breastfeeding or mixed feeding than in the entirely postdelivery time period (Table 8), in whom bottlefeeding predominated. This finding reflects the usual pattern of breastfeeding behavior: women start exclusive or predominant breastfeeding at birth and tend to stop before 6 months.² The median duration of breastfeeding (to any degree) in this sample was 122 days.

Tables 9, 10 and 11 present the average measures of the main variables of interest by method of infant feeding in these three time periods.

² In Canada, by age of 6 months, only 22 to 32% of infants are still breastfed (64).

<u>TABLE 9</u> - Prepregnancy BMI, gestational weight gain, weight after delivery and rate of weight change in 125 women followed from delivery to 3-5 months (91-152 days) postpartum.

Feeding Category	Prepregnancy BMI (kg/m ³)	Gestational weight gain (kg)	Weight after delivery (kg) ⁴	Rate of weight change (kg/day) ^b
Measurcs	Mcan SD (95% CI)	Mean SD (95%CI)	Mean SD (95%CI)	Mean SD (95% CI)
Predom breast	23.1 3 4 (22.1,24.1)	144 40 (132,15.0)	68.3 9.6 (65.4,71.2)	-0.035 0 035 (-0.046,-0.025)
Mixed feeding	22.0 31 (211,22.9)	139 4.6 (12.6,15.2)	64.2 8.9 (61.7,66.7)	-0.022 0.037 (-0.048,-0.028)
Predom. bottle	22 0 2 5 (21.1,22.9)	13.8 4.5 (12 2,15 4)	62.5 74 (59 9,65.1)	-0 038 0.040 (-0.051,-0.024)

* Weight after delivery = prepregnancy weight + weight gain - birthweight - (birthweight/6) -1 (in kg) ^b No significant (p>0.05) differences between groups.

<u>TABLE 10</u> - Prepregnancy BMI, gestational weight gain, weight after delivery and rate of weight change in 176 women followed from delivery to 6-8 months (182-243 days) postpartum.

Feeding Category	Prepregnancy BMI (kg/m ²)	Gestational weight gam (kg)	Weight after delivery (kg)*	Rate of weight change (kg/day) ^b
Measures	Mean SD (95%CI)	Mean SD (95%Cl)	Mean SD (95%Cl)	Mean SD (95% CI)
Predom. breast	22 7 3 4 (21 8,23.6)	12.9 41 (11.8,14.0)	65.4 10 (62 5,68.3)	-0 021 0 025 (-0.028,-0.014)
Mixed feeding Predom. bottle	22.2 3 1 (21 5,22.9) 22.0 2.6 (21.3,22.7)	156 51 (145,16.8) 14.7 4.7 (134,16.0)	66 9 10 (64 6,69.2) 63.5 6 6 (61.7,65.4)	-0 024 0 028 (-0 030,-0 018) -0 027 0.025 (-0 034,-0.020)

* Weight after delivery = prepregnancy weight + weight gain - birthweight - (birthweight/6) -1 (in kg) * No significant (p>0.05) differences between groups.



<u>TABLE 11</u> - Prepregnancy BMI, gestational weight gain, weight after delivery and rate of weight change in 89 women followed from 3-5 months (91 to 152 days) to 6-8 months (182 to 243 days) postpartum.

Feeding Category	Prepregnancy BMI (kg/m²)	Gestational weight gain (kg)	Weight after delivery (kg)*	Rate of weight change (kg/day) ^a
Measures	Mean SD (95%CI)	Mean SD (95%Cl)	Mean SD (95%Cl)	Mean SD (95% CI)
Predom breast	21.9 2.5 (20 8,23.0)	148 35 (133,16.3)	65.2 8 4 (61 6,68 8)	-0.008 0 023 (-0 018,0 002)
Mixed feeding	23.2 3.6 (21.3,251)	15.1 4.4 (12.8,17 4)	68.3 94 (63.4,732)	-0 007 0 023
Predom. bottle	21.9 2.9 (21 1,22.7)	14.6 44 (134,15.8)	64.5 88 (62.2,669)	-0 019 0 033 (-0 028,-0 01)

^a Weight after delivery = prepregnancy weight + weight gain - birthweight - (birthweight/6) -1 (in kg) ^b No significant (p>0.05) differences between groups

It can be noted in Table 9 that in the time period from birth to 3-5 months, those women who predominantly breastfed had slightly but significant higher mean prepregnancy BMIs and weights after delivery than women who mixed fed or predominantly bottlefed their infants. The mean rate of weight change was nonsignificantly slower for the mixed feeding group (ANOVA procedure, p=0.10).

In the subgroup of women followed from birth to 6-8 months postpartum (Table 10), the mixed feeding group had a significantly higher weight gain than the predominant breastfeeding group and a significantly higher weight after delivery than the predominantly bottlefeeding group. Although the mean rate of weight loss was slower for the predominantly breastfeeding group than the two other groups, the 95% confidence intervals substantially overlap (ANOVA procedure, p=0.51).

For the time period from 3-5 months to 6-8 months postpartum (Table 11), the three feeding groups showed similar gestational weight gains, but the mixed feeding group had a nonsignificantly higher mean prepregnancy BMI and a significantly higher weight after delivery than the other two groups. In this time period, the mean rate of weight loss for

the predominantly bottlefeeding group was twice that of the other two feeding groups, but the difference did not reach statistical significance (ANOVA procedure, p=0.19).

Next, we analyzed weight change relative to prepregnancy weight. Most of the women in the study had, by the end of the follow-up, retained weight above their self- reported prepregnancy weight. For example, 89.6% of the 125 women followed from delivery to 3-5 months and 82.4% of the 176 women followed from delivery to 6-8 months weighed more at the end of the follow-up period than in the pregravid state. (These findings should be interpreted cautiously, however, owing to the well-known tendency to underreport prepregnancy weight). The mean difference between the weight at final follow-up and prepregnancy weight was 5.3 ± 5.1 kg for women followed from delivery to 3-5 months and 4.9 ± 5.4 kg for women followed from delivery to 6-8 months. There were no statistically significant differences in retained weight at final follow-up according to method of infant feeding in either time period.

Finally, rate of weight change had a negative significant association with gestational weight gain in all three time periods. Since the magnitude of the association was similar for the three time periods, we can conclude that the effect of gestational weight gain on postpartum weight change does not vary over time.

4.3 RELATIONSHIP BETWEEN RATE OF WEIGHT CHANGE AND METHOD OF INFANT FEEDING

As explained in the Methods (Chapter 3), the overall "follow-up" period was considered as the time between the delivery and the last CLSC visit, while an "interval" was defined as the time between the delivery and the first CLSC visit or between two consecutive CLSC visits. In the next three sections, we present the results of the repeated measures analysis performed with all the data points defining the intervals for all 236 women (i.e., regardless of time period). Consistently, the specific information contributed by all time-varying variables for the calculation of the regression coefficients is in reference to a given interval and not to a given participant (e.g., the same subject may contribute to the analysis as a predominant breastfeeder in one given interval and a predominant bottlefeeder in a later interval). Many of the time-varying covariates were defined to represent the proportion of a given interval in which a specific behavior (i.e., working, dieting, feeding solids, etc.) occurred. The nontime-varying covariates contributed the same information for all the intervals belonging to the same subject (e.g., a subject who is primiparous would remain so for all intervals of the follow-up period).

In order to perform the analyses with type of infant feeding as a categorical timevarying exposure variable, we created two dummy variables to define the three categories of feeding groups for a given interval (predominantly breastfeeding, mixed feeding and predominantly bottlefeeding). The two dummy variables were defined as follows:

dummy 1 = 0 if predominantly breast- or bottlefeeding
dummy 1 = 1 if mixed feeding
dummy 2 = 0 if predominantly breast- or mixed feeding
dummy 2 = 1 if predominantly bottlefeeding

By this definition, the predominantly breastfeeding group represents the reference group, because the value of both dummy variables is 0. Dummy 1=1 and dummy 2=0 denotes the mixed feeding group, and dummy 1=0 and dummy 2=1 denotes the predominantly bottlefeeding group. (Because there are only three feeding groups, the fourth combination (dummy 1=1 and dummy 2=1) does not exist.)

A crude (unadjusted) analysis showed that there was no significant association between the daily rate of weight change and type of infant feeding (Table 12). <u>TABLE 12</u> - Crude (nonadjusted) repeated measures analysis of daily rate of weight change by type of infant feeding

Feeding Method	Regression Coefficient (B)	SE	(95% CI)	P-value
Constant	-0.0329	0.0043	(-0.0413, -0.0245)	<.001
Dummy 1*	0.0076	0.0065	(-0.0051, 0.0203)	.241
Dummy 2 ^b	0.0060	0.0060	(-0.0058, 0.0178)	.313

'dummy 1 = 0 if predominantly breast- or bottlefeeding.

dummy 1 = 1 if mixed feeding

^bdummy 2 = 0 if predominantly breastfeeding or mixed feeding.

dummy 2 = 1 if predominantly bottlefeeding.

The regression equation derived from this table reads:

Rate of weight change, = -0.0329 + 0.0076 (dummy 1), + 0.0060 (dummy 2),

where the index *i* denotes the *ith* postpartum interval.

To interpret this equation, the predominantly breastfeeding group is defined as the reference group, with a weight change equal to the value of the constant (since both dummies assume the value of 0). The rate of weight loss is 0.0076 kg/day slower in the mixed feeding group and 0.0060 kg/day slower in the predominantly bottlefeeding group than in the predominantly breastfeeding group, but these differences are neither statistically significant nor clinically important.

It can be observed that the results of the crude repeated measures analysis are in agreement with those of the analyses by time periods presented in Section 4.2. The

repeated measures analysis, however, results in less misclassification of variables that change over time (e.g., postpartum smoking, dieting, etc.). Also, use of all data points available for each participant increases the power to detect a significant difference in the relationship of interest (e.g., for the analysis by time period from delivery to 182-243 days, 250 data points were used, whereas for the analysis in this section, 449 data points were used).

4.4 RELATIONSHIP BETWEEN RATE OF WEIGHT CHANGE, METHOD OF INFANT FEEDING AND COVARIATES

To asses potential confounding and intervening variables, we analyzed the relationship between the outcome and exposure variables and each of the covariates (one at a time). As shown in Table 13, the outcome variable, rate of weight change for a given interval, was significantly (p<0.05) associated with gestational weight gain, smoking during pregnancy, postpartum working and smoking status, solids and juice intake, gestational age, marital status, maternal birthplace, CLSC attendance and the average time between the two consecutive weights defining the interval and birth ("time variable").

TABLE 13 - Repeated measures analysis of the effect of socioeconomic, gestational and postpartum factors on daily rate of weight change

Variable	Regression coefficient (B)	SE	(95% CI)	p- value
				- value
CONTINUOUS				
Prepregnancy BMI	0 001	0.0008	(-0.001, 0.003)	.059
Maternal height	-0 065	0 0370	(-0.138, 0.008)	.077
Gestational weight gain	-0 003	0.0005	(-0.004, -0.0022)	<.0001
Gestational age at delivery	-0.006	0.0017	(-0.009, -0.002)	.0014
Birthweight	-0.008	0.0055	(-0.019, 0.003)	.151
Maternal education	-0.0003	0.0007	(-0.002, 0.001)	.714
Maternal age at delivery	0 0004	0.0004	(-0.0004, 0.001)	.388
Postpartum working	0.021	0.0087	(0.004, 0.038)	.018
Postpartum exercise	0.007	0.0076	(-0.008, 0.022)	.343
Postpartum dicting	0.016	0.0115	(-0.006, 0.038)	.159
Postpartum smoking	-0 001	0.0005	(-0.002, -0.0003)	.004
Solids intake	0.040	0.0059	(0.028, 0.052)	<.0001
Juice intake	0.026	0.0074	(0.012, 0.041)	.0004
Time variable	0.0003	0.0001	(0.0001, 0.0005)	.0006
DICHOTOMOUS	1			
DICHOTOMOUS:	0.005	0.0005		
Panty	-0.005	0.0025	(-0.010, 0.0002)	.062
0=primiparous				1 1
l=multiparous				
Marital status	-0.006	0.0027	(-0.011, 0.0002)	.045
0 = single/sep/div				
1 = married				
Living situation	-0.003	0.0034	(-0.010, 0.003)	.355
0 = alone				
l = with partner				
Maternal birthplace	-0.010	0.0027	(-0.015, -0.005)	.0002
0 = Canada/US				
1 = Other				
CLSC attended	-0.010	0.0027	(0.004, 0.015)	.0003
0 = Cote des Neiges				
1 = Outremont				
	0.014			
Gestational smoking	0.014	0.004	(0.006, 0,022)	.0007
0 = no smoking				
l = any smoking				
Attendence at Mantest D	0.001	0.000		
Auchuance at Montreal Diet	-0.001	0.003	(-0.007, 0.005)	.699
Dispensary				1 1
0 = no				
I = yes				

60

It can be observed, for example, that women who gained more weight during pregnancy had a faster rate of postpartum weight loss (negative regression coefficient), whereas those who had a higher prepregnancy BMI tended to show postpartum weight gain (positive regression coefficient).

As shown in Table 14, type of infant feeding was significantly (p<0.05) associated with postpartum working, dieting, smoking and solids and juice intake. The relationship between infant feeding type and the nontime-varying covariates could not be assessed, owing to constraints in the BMDP program with respect to the handling of categorical time-varying variables. (According to the BMDP support representative, the program does not allow a model in which a <u>categorical</u> time-varying variable or any nontime-varying variable is the dependent variable, making it impossible to examine the relationship between two of these variables.) In contrast, the relationships between type of infant feeding and the time-varying covariates (which are continuous) could be examined by using the latter as the dependent variables and type of infant feeding as the independent variable (Table 14).

TABLE 14 - Repeat	ed measures	analysis	of various	postpartum	factors	and	type	of
infant feeding								

Variables	Regression coefficient (B)	SE	95% CI	p-value
Postpartum working	Dummy 1* 0.094	0.035	(0.025, 0.163)	.008
	Dummy 2 ^b 0.170	0.034	(0.104, 0.237)	<.0001
Postpartum dieting	Dummy 1 -0.017	0.025	(-0.066, 0.032)	.500
	Dummy 2 0.099	0.025	(0.050, 0.148)	.0001
Postpartum exercising	Dummy 1 0.012	0.039	(-0.065, 0.088)	.755
	Dummy 2 0.037	0.038	(-0.038, 0.112)	.336
Postpartum smoking	Dummy 1 0.183	0.184	(-0.178, 0.544)	.319
	Dummy 2 0.410	0.204	(0.010, 0.810)	.044
Solids intake	Dummy 1 0.063	0.045	(-0.025, 0.151)	.158
	Dummy 2 0.226	0.039	(0.150, 0.302)	<.0001
Juice intake	Dummy 1 0.087	0.041	(0.007, 0.167)	.0347
	Dummy 2 0.189	0.038	(0.115, 0.263)	<.0001
Time variable	Dummy 1 -2.032	3.259	(-8.420, 4.356)	.533
	Dummy 2 -3.129	2.951	(-8.913, 2.655)	.289

^aDummy 1 = 0 if predominantly breast-or bottlefeeding; dummy 1 = 1 if mixed feeding. ^bDummy 2 = 0 if predominantly breastfeeding or mixed feeding; dummy 2 = 1 if predominantly bottlefeeding



It can be observed that the proportion of time duirng the interval in which women were working and feeding juice was greater in the predominantly bottlefeeding group than in the mixed feeding group and, at the same time, greater in the mixed feeding group than in the predominantly breastfeeding group. On the other hand, the proportion of time duirng the interval in which women were dieting and feeding solids was greater in the predominantly bottlefeeding group than in both the mixed feeding and predominantly breastfeeding groups. Similarly, women in the predominantly bottlefeeding group were more likely to have smoked in a given interval than women in the mixed feeding and predominantly breastfeeding groups. The proportion of time during the interval in which women were exercising and the time variable showed no statistically significant association with type of infant feeding.

Several associations of interest between pairs of covariates (and their levels of statistical significance) are presented in Table 15 and 16. Table 17 shows the relationship between pairs of categorical nontime-varying covariates.

<u>**TABLE 15</u>** - Repeated measures analysis of pairs of time-varying covariates or between time-varying and nontime-varying covariates</u>

Dependent variable [*]	Independent variable	Coeffi- cient(ß)	SE	95% CI	p-value
Postpartum smoking	Prepregnancy BMI Gestational weight gain Gestational smoking Birthweight Postpartum exercising Postpartum working Solids intake Place of birth CLSC of attendance	0.306 -0.109 12.888 -0.658 -0.286 0.232 0.260 1.457 -0.793	0.100 0.068 0.791 0.756 0.228 0.214 0.116 0.358 0.370	(0.110, 0.502) (-0.243, 0.024) (11.3, 14.44) (-2.134, 0.830) (-0.732, 0.161) (-0.187, 0.651) (0,032, 0,487) (0.755, 2.159) (-1.52, -0.068)	.0023 .109 <.001 .386 .211 .278 .0247 <.0001 .032
Postpartum exercising	Postpartum dicting Postpartum working Place of birth	0.507 0.009 0.049	0.069 0.051 0.021	(0.372, 0.642) (-0.091, 0.109) (-0.020, 0.062)	<.0001 .854 .017
Solids intake	Parity Birthweight Place of birth Postpartum working Juice intake CLSC of attendance	0.004 -0.015 0.008 0.393 0.635 0.045	0.015 0.033 0.016 0.058 0.047 0.016	(-0.026, 0.033) (-0.080, 0.049) (-0.023, 0.039) (0.279, 0.507) (0.543, 0.727) (0.014, 0.076)	.812 .648 .615 <.0001 <.0001 .005
Time variable	Postpartum smoking Postpartum dieting Postpartum working Solids intake Place of birth CLSC of attendance	-0.015 -8.539 -3.535 -6.983 -1.592 3.413	0.231 5.897 4.379 3.177 1.386 1.401	(-0.468, 0.438) (-20.10, 3.019) (-12.12, 5.048) (-13.21, -0.756) (-4.309, 1.125) (0.667, 6.159)	.948 .148 .420 .028 .251 .015

"When examining the relationship between a time-varying and a nontime-varying covariates, the time-varying covariate was used as dependent variable.

TABLE 16 - Simple linear regression between pairs of nontime-varying covariates

Dependent variable	Independent variable	Coefficient (B)	SE	95% CI	p-value
Prepregnancy BMI (kg/m ²)	Gestational weight gain Parity Birthweight Maternal age Maternal education Marital status Living situation Place of birth CLSC attended	-0.169 1.484 0.904 0.051 -0.083 1.014 0.915 -0.514 -0.032	0 043 0.429 0 473 0.038 0.063 0 470 0.622 0.477 0.483	(-0 253, -0 085) (0 643, 2 325) (-0 023, 1 831) (-0 024, 0 126) (-0 207, 0 041) (0 093, 1 935) (-0 304, 2.134) (-1 449, 0.421) (-0.979, 0.915)	0001 .0006 057 177 187 .032 .143 .283 .947
Gestational weight gain (kg)	Panty Height Gestational age Birthweight Maternal age Maternal education Marital status Living situation Place of birth CLSC attended MDD ^a attendance	-2 425 0.132 0.535 2.295 -0.091 0.028 -1.411 -2.133 -1.373 1.304 0 047	0 631 0.048 0.217 0.690 0 056 0.093 0.697 0.911 0.703 0.710 0.763	(-4 900, -1 188) (0.038, 0 226) (0 110, 0.960) (0 943, 3 647) (-0 201, 0 019) (-0 154, 0 210) (-2 777, -0 045) (-3.919, -0 347) (-2.751, 0 065) (-0 088, 2.696) (-1 449, 1 543)	0002 006 .015 001 106 .763 044 020 .052 .068 .951
Maternal education (years)	Parity Matemal age Mantal status Living situation Place of birth CLSC attended	-0.908 0.182 1.118 2.361 -2.251 2.286	0.460 0.039 0.497 0.634 0.484 0.490	(-1.810, -0 006) (0.106, 0.258) (0 144, 2 092) (1.118, 3 604) (-3 200, -1.302) (1 326, 3.246)	.050 .0001 025 .0002 0001 .0001
Maternal age at delivery (years)	Parity Mantal status Living situation Place of birth CLSC attended	2.768 3.056 1.784 0.384 -0 989	0 732 0.791 1.067 0.822 0 826	(1 333, 4.203) (1.506, 4.606) (-0.307, 3.875) (-1 227, 1 995) (-2.608, 0.630)	.0002 .0001 096 641 .233

^aMontreal Diet Dispensary

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Variable	Variable	Relative Risk	(95% CI)
Parity 0=primiparous 1=multiparous	Place of birth 0=Canada/US 1=Other	1.67	(1.24,2.07)
	Mantal status 0=single/scp/div 1=marned	2.12	(1.41,3.19)
	Living situation 0=alone 1=with partner	1.52	(0.91,2.55)
	CLSC attended 0=Côte des Neiges 1=Outremont	0.86	(0.74,1.01)
Maternal birthplace 0=Canada/US 1=Other	Marital status 0=single/sep/div 1=married	1.42	(0.96,2.11)
	Living situation 0=alone	0.40	(0.94,0.17)
	CLSC attended 0=Côte des Neiges 1=Outremont	0.50	(0.41,0.62)
Marital status 0=single/sep/div	Living situation 0=alone	13.3	(6.79 ,26 .07)
	CLSC attended 0=Côte des Neiges 1=Outremont	0.94	(0.79,1.12)
Living situation 0=alone 1=with partner	CLSC attended 0=Côte des Neiges 1=Outremont	1.30	(1.05,1.61)

4.5 MULTIVARIATE REPEATED MEASURES ANALYSIS.

As opposed to the analysis presented in section 4.4, the multivariate models presented in this section analize the effects of several covariates simultaneously. Potentially confounding covariates representing socioeconomic, gestational and postpartum characteristics of the study subjects were included in these multivariate repeated measure analyses. The potential confounders were chosen based on knowledge available from previous research in the field. When many variables were available for one area of interest (i.e., socioeconomic status), the variables included in the model were chosen based on the significance of their association with both the exposure and the outcome variables. Also, the quadratic term of the time variable was introduced in the model to test if the relationship between time and rate of weight change was parabolic instead of linear.

The main procedure used was a backward elimination in which the decision to "eliminate" variables was based on significance testing of the regression paramete's (Wald test) and the likelihood ratio test statistic. To avoid collinearity problems, the nonquadratic term of the time variable, prepregnancy BMI and gestational weight gain were added together in a single step and thereafter deleted if nonsignificant. Unfortunately, the interaction terms to test for the role of prepregnancy BMI and gestational weight gain as effect modifiers of the exposure/outcome association could not be included in the multivariate analysis, owing to serious problems with collinearity. Therefore, the initial model was:

(rate of weight change), = (type of infant feeding), + (solids intake), + (parity), + (birthweight), + (height), + (postpartum smoking), + (postpartum working), * + education + age + CLSC of attendance + place of birth + (time variable²),

where the index *i* denotes the *ith* postpartum interval

^aPostparium working was included as a measure of socioeconomic status, not of physical activity

The final regression model is presented in Table 18.

<u>TABLE 18</u> - Multivariate repeated measures analysis of daily rate of weight change (outcome variable), type of infant feeding (exposure variable) and various sociodemographic, gestational and postpartum covariates.

Variable	Regression Coefficient (B)	SE	(95% CI)	P-value
Constant	-0.042	0.0119	(-0.065, -0.019)	.0004
Type of infant feeding ^a :dummy 1 dummy 2	0.003 -0.003	0.0057 0.0056	(-0.008, 0.014) (-0.014, 0.008)	.5475 .5793
Gestational weight gain	-0.003	0.0005	(-0.004, -0.002)	<.0001
Postpartum smoking ^b	-0.024	0.0069	(-0.038, -0.011)	.0006
Infant's solid intake°	0.045	0.0057	(0.034, 0.056)	<.0001
Matemal place of birth ^d	-0.005	0.0025	(-0.011, -0.001)	.0365
Time variable ^e (t)	0.0014	0.0004	(0.0006, 0.002)	.0001
Quadratic term for time variable (t ²)	-0.00001	0.000003	(-0.00002, -0.000004)	.0035

"Dummy 1 = 0 if predominantly breast- or bottlefeeding; dummy 1 = 1 if mixed feeding.

Durnmy 2 = 0 if predominantly breastfeeding or mixed feeding; dummy 2 = 1 if predominantly bottlefeeding

^bNo postpartum smoking = 0, any postpartum smoking = 1

Proportion of the postpartum interval in which solids were taken by the infant.

^dCanadian or U.S. born = 0; other = 1.

"Average time in days between birth and the two consecutive weights defining a postpartum interval.

A final analysis was performed to test for the possible modifying effect of time on the infant feeding/postpartum weight change relationship. A regression analysis was performed including in the model all the variables presented in Table 18 and an interaction term between time and infant feeding. The time*infant feeding term was not statistically significant.

5. DISCUSSION

5.1 SUMMARY OF FINDINGS

The findings of this study suggest no significant difference in the rate of weight loss in the first 9 postpartum months between women who either exclusively breastfeed or feed their infants an average daily formula volume of 4 ounces (120 ml) or less (predominantly breastfeeding), women who feed their infants more than 4 ounces of formula/day but more than 4 ounces of breast milk/day (mixed feeding) and women who feed their infants 4 ounces of breast milk or less per day or exclusively bottlefeed (predominantly bottlefeeding). Other authors have reported no difference in the rate of weight loss between breastfeeding and bottlefeeding women in the first 3 months (10,41,42,43,63), 6 months (63) and 12 to 24 months postpartum (47,55).

To have a more tangible idea of what these results represent and compare them with the findings of previous studies, we examined summary measures for three time periods of follow-up. For the group of women followed from birth to 6-8 months postdelivery, the average rate of weight change was -0.63 kg/month for the predominantly breastfeeding group and -0.81 kg/month for the predominantly bottlefeeding group. When compared with studies having similar follow-up periods, these rates are comparable to those reported by Naismith and Ritchie (10) (see Table 1) but slower than those reported by Brewer et al. (42) and Kramer et al. (63), and by Sadurskis et al. (15) for breastfeeding women only. For the time period from birth to 3-5 months postdelivery, the rate of weight change was -1.05 kg/month for the predominantly breastfeeding group and of -1.14 kg/month for the predominantly bottlefeeding group. These rates are comparable to those reported by Naismith and Ritchie (10) and Butte et al. (42) and Kramer et al. (63). The high rates of weight loss in these two latter studies may be explained by: 1) the initial weights at

1-3 days postdelivery include fluid that is rapidly lost during the first days postpartum [Naismith and Ritchie (10) measured the initial weights at 10 days postdelivery] and 2) the average gestational weight gains were higher [15.2 (42) and 17.5 (63)] than in other studies.

A considerable number of women in the present study weighed more at the last CLSC visit than they did after delivery (after correcting for the weight of the infant, placenta and amniotic fluid). This finding is comparable to that of Allen and Manning-Dalton, who reported that 22% of study women gained weight in the postpartum period (12).

In the repeated measures analysis, the nonsignificant crude association between method of infant feeding and postpartum weight change was not modified after adjusting for potential confounders (see Table 18). The results of the repeated measures analysis were consistent with those of the analysis by time periods.

Unmeasured sources of confounding may have arisen if the reasons why mothers selected their "exposure" (breastfeeding or not) were associated with the rate of weight change. It is known that mothers who choose to breastfeed differ in important attitudinal aspects from those mothers who bottlefeed (44). If these attitudes influence the rate of weight loss, then "confounding by indication" may have been introduced in the association between lactation and weight loss. Unfortunately, owing to study design and feasibility issues, the only attitudinal measures recorded were a rough self-reported assessment of postpartum dieting and exercise practices. In our analysis, it was shown that postpartum exercising was not related to either method of infant feeding or rate of postpartum weight change; the proportion of the interval during which women were dieting was significantly greater in the predominantly bottlefeeding group than in the mixed feeding and breastfeeding groups, but there was no relationship between postpartum dieting and rate of postpartum weight loss.

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With respect to other sources of analytic bias, there were several sources of possible distortion in the selection and follow-up of the study sample. First, the characteristics of the target population (i.e., all the women attending the CLSC for their infants' immunizations) are not known, but there is no indication that the sample selected was distorted with respect to the relationship of interest. The possibility of selective contact to seek participation in the study varied with the different persons involved in recruitment: the CLSC nurses and two of the investigators (LNH, RT). If the CLSC nurses had previously encountered the prospective participant, they were more likely to know her exposure status but still unlikely to know or have remarked on her rate of weight change. When the mother was recruited by the investigators, the probability of selective contact of potential subjects was very small, since this was their first contact with her and they were unaware of either her exposure or outcome status. The degree and reasons for refusal to participate were not recorded, but nonparticipation appeared to be mainly related to lack of interest in participating in a research project.

Owing to the study design, there were no losses to follow-up, since every subject with at least one weight and the corresponding telephone questionnaire was retained for the analysis.

Lastly, energy intake and expenditure play important roles in the relationship between lactation and weight change. Manning-Dalton and Allen, for example, treated energy intake as a confounder and adjusted for its effect in their multivariate analysis (when energy intake was entered in the multiple regression model, most of the effect of extent of lactation on weight change disappeared) (12). Proceeding in this way seems questionable, since it could be argued that both energy intake and expenditure lie on the casual path between the effect of lactation and weight change. If those mothers who breastfeed have larger energy intakes and exercise less as an energy-sparing adaptation, then these energy-related mechanisms may explain the lack of difference in postpartum weight loss between feeding groups (despite the extra energy costs of lactation in breastfeeding mothers), and adjusting for them would lead to a biased estimation of the
exposure-outcome association. In the present study, the main question we aimed to answer is at what rate do the mothers who feed their infants in different ways lose weight; we did not aim to identify the exact metabolic mechanisms by which these different rates occur. We therefore decided not to collect detailed information on energy intake and expenditure. The only information collected involved crude indicators of postpartum exercise, working and dieting practices. As mentioned, postpartum exercise was not related to either exposure or outcome, and postpartum dieting was associated with exposure but not with outcome. Postpartum working or studying outside the home was related to both exposure and outcome but was not retained as a significant predictor of weight change in the multivariate analysis. Also, since detailed information on the quantity and type of work was not recorded, the validity of using this variable as a measure of energy expenditure is questionable; its inclusion in the multivariate analysis was based on its relationship to socioeconomic status.

In the multivariate repeated measures analysis, several variables proved to be significant predictors of postpartum weight change. Gestational weight gain was retained as an important predictor of postpartum weight loss; women who gained more weight during pregnancy had faster rates of postpartum weight loss. This finding is consistent with those of previous reports (41,42,63). Postpartum smoking was also a predictor of weight change; women who smoked at all during a given interval lost weight faster than those who did not smoke. This variable has not been evaluated in previous research. The proportion of an interval during which solids were taken was also a significant predictor; the infant's receipt of solids for a large proportion of the interval was associated with weight gain. This latter finding is more difficult to explain physiologically than the two previous findings and may represent a marker for other maternal attitudinal factors.

Women born in Canada or the U.S. tended to lose weight more slowly than those born elsewhere. This variable may be a measure of socioeconomic status; immigrant women were more likely to receive unemployment insurance or welfare, were less educated, had higher parity and were more likely to be living alone. Even though a largely nonsmoking group, immigrant women gained less weight during pregnancy and were more likely to attend the Montreal Diet Dispensary for dietary counselling and food supplementation. These findings may help explain the observed effect of maternal birthplace on rate of weight change. It could be postulated that economically disadvantaged women such as this group of immigrants may have low income levels that act as barriers to optimal nutrition (44). If immigrant women are more likely to be at nutritional risk and less likely to have access to adequate dietary intake during the postpartum period (whether lactating or not), these factors may result in a faster weight loss due to utilization of body fat stores [a mechanism postulated in developing countries for lactating women with increased energy demands (62)]. It is worth noting that the immigrant group comprised a very diverse ethnic mix. Women belonging to some ethnic groups may have culturallybased restrictions on maternal diet or behavior that run counter to clinical advice (44).

Lastly, the time variable was significantly retained as a predictor of weight change; later intervals since birth were associated with weight gain. This finding is in agreement with those observed in previous reports, where faster rates of weight loss are consistently found in those studies in which the initial weight is measured close to delivery and the period of follow-up is short. The regression coefficient for the quadratic term of the time variable was statistically significant, indicating that the relationship between rate of weight loss and time (after controlling for other covariates) is parabolic and not linear. The regression coefficient for this second-order term (t²) is in the opposite direction from that of the basic term (t). The minimum point in the curve is 140 days (as calculated from the equation: $0.0014 \text{ t} - 0.00001 \text{ t}^2 = 0$), indicating that in the first 140 postpartum days, the longer and further away from birth an interval, the slower the rate of weight loss (consistent with the concept of postpartum diuresis), whereas after the 140th postpartum day, the longer and further away from birth the interval is, the faster the rate of weight loss.

5.2 LIMITATIONS

The limitations of this report will be discussed under four headings: study design, definition of variables, evaluation of assessing modifiers and external validity.

5.2.1 Study design

Women participated in the study for different lengths of time and had different numbers of contacts and intervals between contacts, thus increasing the complexity of the statistical analysis and thereby rendering the results less transparent. The use of a "time" variable in the statistical analysis accounted for these differences introduced by design. This variable represented the number of days between birth and the midpoint of the interval comprising two consecutive weights; it thereby accounted for both differences in duration of the intervals and timing since birth.

5.2.2 Definition of variables

We encountered two main problems in defining the outcome variable. First, there was no documented early postpartum weight to use as a baseline to calculate the rate of weight change. We were therefore obliged to estimate this weight by subtracting, from the weight at the end of pregnancy, the self-reported weight of the infant and uniform estimates (not individual measures) of the weights of the placenta and amniotic fluid. Second, the weights actually used to calculate the weight at the end of pregnancy (i.e., prepregnancy weight and gestational weight gain) were self-reported.³

³When the participant was uncertain of her prepregnancy weight or gestational weight gain, the accuracy of the weights was verified with the physician providing her prenatal care and, if this information was unavailable, the subject was deleted from the analysis.

The exposure variable was defined to represent the extent of lactation between the two consecutive weights defining an interval and was subsequently categorized into three groups according to the intake of breast milk. Ideally, this variable should have been calculated from actual measurements of milk consumed by the infants. This would have involved weighing infants before and after feeds for several 24-hour periods during follow-up, because of high intra-subject variability in daily milk volume (12). This procedure is obviously not feasible in a large epidemiologic study such as this. In our study, we assessed (by questionnaire) the average volume of formula consumed, by month, for each infant not exclusively breast- or bottlefed and deduced the corresponding average breast milk intake using previously validated estimates of age-specific breast milk volumes. Even though our procedure is imprecise, we considered it acceptable to classify women into feeding categories, despite a certain degree of inevitable nondifferential misclassification of women whose infant feeding practices lay close to the cut-offs defining the categories.

5.2.3 Assessing effect modifiers

One of the aims of this study was to evaluate if the effect of lactation on weight loss varies according to maternal prepregnancy body mass index (BMI) and/or weight gain during pregnancy. Unfortunately, owing to serious problems with collinearity, the interaction terms to test for the role of these two variables as effect modifiers could not be included in the multivariate analysis. Therefore, we were unable to accomplish this aim.

5.2.4 External validity

There are important differences in baseline characteristics between the study sample and the external population to which we would like to generalize the results. Two sets of data from the year 1986-87 characterizing this external population were available to compare to the study sample: 1) data from all new mothers in the Ste-Justine DSC

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territory (which also includes the areas of Côte St-Luc and Hampstead) and 2) data from all women who had been visited at home by the CLSC nurses and had completed the Culture et Grossesse questionnaire (68.8 % of the women of the territory) (67).

The study sample had a higher proportion of immigrants, single women and adolescents than either of the external groups mentioned above. Women in the study sample were more likely to have an incomplete secondary education, to be on unemployment insurance or welfare and to be living alone than women completing the Culture et Grossesse questionnaire; also, they were shorter on average and smoked less during pregnancy. There were no differences, however, in the percentage of women with low prepregnancy weight (<45 kg) or low gestational weight gain (<10 kg). With respect to method of infant feeding, study women initiated breastfeeding more frequently than women from the DSC territory. We have no information on the rate of postpartum weight change in either of the external groups. Since there was no indication that the study sample was different from these larger, external groups of women in the relationship of interest, this unrepresentativeness may not necessarily compromise the external validity of the study.

5.3 STRENGTHS

The strengths of this study will be discussed under two headings: contributions to existing knowledge and methodologic improvements.

5.3.1 Contributions to existing knowledge

Our study provides several contributions to the existing knowledge concerning the relationship between infant feeding and postpartum weight loss. First, we found no differences in the rate of postpartum weight loss in women who either predominantly breastfeed, mix feed or predominantly bottlefeed their infants. Second, we confirmed

the role of gestational weight gain as an important predictor of postpartum weight loss. Third, we identified several new determinants of postpartum weight change: postpartum smoking, maternal birthplace and duration of solids intake (the latter probably representing a marker for other attitudinal factors). Finally, we have shown that weight change is parabolic, rather than linear, over time.

In addition, ours was the first study on maternal nutrition in a developed country to be based on a multi-ethnic study sample. Within our sample, many more women were on unemployment insurance and welfare (indicating lower socioeconomic status) than in previous studies. (Since infants weighing less than 2,000 g were excluded, however, the sample was restricted to women with favourable obstetrical outcomes). Other maternal and infant characteristics in our smaple were not unusual.

5.3.2 Methodologic improvements

Our study has three important methodologic advantages over previous studies: 1) good statistical power, 2) appropriate classification of exposure and 3) assessment and control of time-varying covariates. The statistical power of this study to detect significant differences in postpartum weight change between feeding groups was enhanced by studying a larger sample and by using an unbalanced repeated measures analytic strategy, whereby all data points available for all participants were used. The choice of an unbalanced repeated measures analytic strategy permitted not only 'he use of an appropriate multivariate model to control for covariates, but also reduced misclassification of the time-varying exposure and covariates, thus providing a better characterization of the effects of behaviors (e.g., infant feeding, postpartum smoking, etc.) that change over time.

5.4 CLINICAL AND PUBLIC HEALTH IMPLICATIONS

Women who plan to breastfeed or who are breastfeeding should be given realistic, health-promoting advice about weight change during lactation (44). Women should be screened for nutrition-related problems, such as the risk of becoming nutritionally depleted or of developing adult-onset obesity. They should be also evaluated for the risk of early cessation of breastfeeding as a consequence, among others, of unfulfilled expectations regarding postpartum weight loss.

Women should be advised that it is normal to lose weight during the first 6 months of lactation. The average monthly rate of weight loss is 0.5 to 1 kg after the first month postpartum (44). There seems to be no difference in the rate of postpartum weight loss in women who are either predominantly breastfeeding, mixed feeding or predominantly bottlefeeding. However, not all women lose weight in the postpartum period; some women gain weight postpartum, whether or not they breastfeed.

Health professionals should elicit the mother-centered beliefs that reinforced her decision to breastfeed. Women who choose to breastfeed in the hope of losing weight faster may be at risk for terminating breastfeeding prematurely if that hope is disappointed. Health professionals should explain the normal pattern and extreme variability of postpartum weight change.

5.5 NEED FOR FURTHER RESEARCH

The attitudes and beliefs towards postpartum change among mothers and health professionals need to be further explored. Also, the knowledge that women have and the advice that they receive require further investigation. Such information would be useful in the development of educational material for health professionals and mothers-to-be. For those women planning to diet during lactation, the effect of prolonged periods of energy restriction on milk volume and nutrient stores should be better documented. The threshold below which energy intake is insufficient to support adequate milk production has yet to be determined. The identification of this level of energy intake would be useful in establishing guidelines for women who want to breastfeed but also want to restrict their energy intake to lose weight (44). Also, it would be useful to know if women who breastfeed experience faster rates of weight loss after cessation of breastfeeding than women who do not breastfeed at all. All this information would be important for women who want to breastfeed or are breastfeeding but are concerned about their weight.

There is a need to identify groups of lactating women who are at risk of becoming malnourished. The corresponding risks factors, and their combined effects, should be better characterized. These groups of women could be targeted by public health interventions that would adequately support lactation while taking maternal health consequences into consideration.

The consequences of lactation for long-term maternal energy balance are unclear and require detailed investigation (44). In particular, data are insufficient to determine whether lactation influences the risk of adult-onset obesity.

6. CONCLUSION

Few previous studies have examined the effects of lactation on the weight and body composition of well-nourished women. The results of these studies have not substantiated the widely-held assumptions that lactation is associated with increased catabolism of fat stores and hence with faster loss of weight gained during pregnancy.

The primary objective of this study was to compare the patterns of weight change in a well-nourished, mixed-race, multi-ethnic population in Montreal according to type of infant feeding method used during the first 9 months postpartum. Two hundred and thirty six women were recruited into the study during their visit to the CLSC Côte des Neiges or CLSC Outremont immunization clinics if they had a baby 8 months of age or younger. Each participant was weighed at the initial CLSC visit and reweighed whenever possible at subsequent CLSC visits until no later than the 9th month postpartum. After each CLSC visit, a questionnaire assessing the method of infant feeding (predominantly breastfeeding, mixed feeding or predominantly bottlefeeding) and potential confounders was administered by telephone. Inherent to this design was that study women participated during different time periods postpartum, for different durations of time and with different numbers of contacts and intervals between contacts.

In order to summarize the main variable of interest, rate of postpartum weight loss, the overall analysis was based on three different groups of women followed for different lengths of time. This analysis revealed that although the predominantly bottlefeeding group tended to loose weight at a faster average rate than the mixed feeding and breastfeeding group, there were no statistically significant differences in the rate of weight loss by category of infant feeding. Based on BMDP 5V.8, a multivariate program for unbalanced repeated measures analysis, there were no statistically significant differences in the rate of weight loss by category of infant feeding. Based on BMDP 5V.8, a multivariate program for unbalanced repeated measures analysis, there were no statistically significant differences in the rate of weight loss by category of infant feeding either in the unadjusted analysis or after controlling for potential confounding variables.

The multivariate analysis identified important predictors of postpartum weight loss. Women with larger gestational weight gains and those who smoked during the postpartum period had faster rates of postpartum weight loss. Women born in Canada or the U.S. tended to lose weight more slowly than those born elsewhere, but this variable may be a proxi for socioeconomic status. Also, receipt of solids for a high proportion of a given interval was actually associated with postpartum weight gain; this variable may represent a marker for other maternal attitudinal factors. Lastly, the relationship between time after birth and postpartum weight change was found to be parabolic rather than linear.

The information provided by this study should help health professionals to provide realistic, health-promoting advice about postpartum weight change to women making decisions about how to feed their infants.

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