Effects of Maternal Caloric Restriction and Exercise during Lactation

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ABSTRACT In affluent populations, breast-feeding women often wish to return to their prepregnancy weight as soon as possible postpartum and may restrict energy intake or increase exercise to achieve this goal. Gradual weight loss (≤2 kg/mo) seems to have no adverse effect on milk volume or composition, provided that the mother is not undernourished and is breast-feeding her infant on demand. Aerobic exercise improves cardiovascular fitness and does not affect milk energy transfer to the infant, but exercise alone is not likely to increase the rate of weight loss unless dietary intake is controlled. Less information is available on the effect of rapid weight loss. Data from a recent randomized intervention trial indicate that a short-term (11 d) energy deficit of 35%, achieved by dieting or a combination of dieting and increased exercise, results in weight loss >1 kg/wk and does not adversely affect lactation. Exercise enhances maintenance of lean body mass and is therefore a recommended component of any weight loss program. Maternal plasma prolactin concentration generally increases under conditions of negative energy balance, which may serve to protect lactation. Further research is required on the long-term effect of energy restriction and on the effects of energy balance in lactating women with low fat reserves. J. Nutr. 128: 3865–3898, 1998.

KEY WORDS: • lactation • exercise • energy intake • milk

During the postpartum period, many women are eager to lose weight, but concerned that dieting and exercise may adversely affect breast milk volume or composition. In the lactating woman, energy needs are increased by ~30% over those of nonpregnant, nonlactating women (Dewey 1997). Gradual weight loss during lactation (~0.5 kg/mo) is common in populations with a relatively high average body mass index and is not thought to pose any risk (Institute of Medicine 1991). Nonetheless, there is uncertainty regarding the potential effect of lactation on deliberately restricting energy intake or increasing energy expenditure, particularly if this results in rapid weight loss.

There are several ways in which the effects of negative energy balance during lactation can be examined. Some investigators have studied whether breast milk volume or energy output is associated with the magnitude of weight change during the postpartum period. In most populations, no significant relationship between maternal weight loss and lactation outcomes has been found (Brown and Dewey 1992). Similarly, maternal body mass index is generally not associated with milk volume or total milk energy output (Prentice et al. 1994). However, among women with low fat reserves, energy balance may be more critical. For example, Brown et al. (1986) observed that breast milk energy output was greater among Bangladeshi women who gained >200 g during the first 3 mo postpartum than in those who gained <200 g (interestingly, most of the women in that study gained weight during lactation, in contrast to the situation in more affluent populations). There are several inherent limitations of such observational studies, however. The chief drawback is the difficulty of disentangling potentially confounding factors such as maternal activity patterns, time devoted to breast-feeding, illness patterns and infant birthweight. The risk of drawing erroneous conclusions from observational studies is illustrated by data on seasonal patterns of food intake and milk volume in developing countries. In The Gambia, for example, Prentice et al. (1986) observed that infant breast milk intake declined during the rainy season, which is also the time when mothers typically lose weight. It was initially tempting to assume that maternal energy restriction was responsible for the decrease in breast milk volume, but a subsequent maternal dietary supplementation study failed to show any increase in milk volume even during the rainy season. The authors concluded that the seasonal variation in milk volume was related to other factors such as increased infant morbidity and altered breast-feeding patterns in response to maternal agricultural activity during the rainy season.

Another approach is to reverse experimentally a presumed negative energy balance by supplementing undernourished women with additional food and observe whether lactation outcomes improve. This strategy has been attempted numerous
times, but the results have been conflicting (Brown and Dewey 1992, Rasmussen 1992). Most of the studies have had serious methodological flaws such as the following: 1) selecting a sample that is not truly undernourished; 2) not using procedures of random assignment; 3) measuring milk volume and energy density with inadequate methods; or 4) including subjects who did not maintain exclusive breast-feeding during the study. In general, the data have suggested little or no effect of supplementation on milk energy output, except possibly among women with very low initial fat stores. However, these findings may or may not be relevant to the situation in more affluent populations in which women who are relatively well nourished go on a weight-reduction diet.

This paper will focus primarily on the third approach to studying the effect of negative energy balance during lactation, which is through experimental studies in which energy intake and/or expenditure are modified so as to increase the rate of weight loss. Before reviewing these studies, however, it is important to emphasize the key role of the infant in determining the volume of milk produced. It is well known that the frequency and intensity of infant suckling are the principal factors affecting both the endocrine and the autocrine regulation of milk synthesis (Daly and Hartmann 1995a and 1995b). Therefore research on the influence of maternal nutrition or exercise on lactation must take into account the modifying effect of infant suckling behavior.

**EFFECTS OF CALORIC RESTRICTION DURING LACTATION**

The effects of caloric restriction during lactation have been studied with the use of several different animal models. Findings from studies with rats are summarized in another paper in these proceedings (Rasmussen 1998). The rat model provides important insights regarding physiologic changes in response to high energy stress, but the results may not apply to humans because the energy demand of lactation as a proportion of total energy needs is much higher in rats than in humans. Other primates are considered to be good models for human lactation, but such studies are rare. Roberts et al. (1985) investigated whether milk output of baboons was affected by energy restriction at either 80 or 60% of ad libitum intake. There was no significant effect at the moderate (80%) level of restriction, but milk output was significantly lower in those given only 60% of energy needs. These results suggested that there may be a threshold effect of negative energy balance on lactation, i.e., that milk output is affected only when energy restriction is relatively severe.

Such experiments are difficult to conduct in humans, for both practical and ethical reasons. Studies of short-term fasting (<24 h) during Ramadan (Prentice et al. 1984) and under more controlled experimental conditions (Neville and Oliva-Rashch 1987) have shown no effect on milk volume. Strode et al. (1986) examined the effect of 7 d of caloric restriction by comparing the breast milk volume and composition of 14 exclusively breast-feeding women who voluntarily reduced their energy intake with those of a control group of eight women who did not change their diet. Average energy intake during the diet week in the experimental group was 68% of base line. In the group as a whole, there was no significant effect of energy restriction on milk volume during the diet week. However, during the week after the diet (when subjects had returned to their usual intake), subjects who had consumed $<6.28 \text{ MJ/d} (1500 \text{ kcal/d})$ during the diet week tended to exhibit a decrease in milk volume compared with those who had consumed $>6.28 \text{ MJ/d}$ during the diet week. Within the experimental group, change in prolactin concentration after energy restriction was positively correlated with milk volume in the diet week. The results were consistent with those of the baboon study and implied that there also might be a threshold effect of energy restriction during lactation in humans.

However, there were several important limitations to the study design: women were not randomly assigned to the experimental vs. control groups, and milk samples were collected at only one feeding rather than throughout a 24-h period. In addition, because the intervention lasted for only 1 wk, the effects of longer-term energy restriction are unknown.

More recently, Dudieker et al. (1994) measured milk volume and composition of 33 exclusively breast-feeding women who enrolled in a 10-wk weight-loss program beginning at 4–14 wk postpartum. During the intervention, energy intake averaged about 77% of base-line intake. Weight loss of the 22 women who completed the program averaged 4.8 kg during the 10-wk intervention. Their average milk volume increased slightly, from 759 to 802 mL/d, during this period. The authors concluded that modest weight loss (~0.5 kg/wk) by healthy breast-feeding women does not adversely affect lactation. However, the lack of a control group limits the inferences that can be made from this study. Furthermore, the relatively high dropout rate (33%) is of concern, because those who dropped out tended to have lower skinfold thickness, energy intake and milk volume at base line, all of which might have made them more vulnerable to the effects of energy restriction than those who completed the study.

**EFFECTS OF EXERCISE DURING LACTATION**

Aside from restricting energy intake, the only other way of modifying energy balance is to increase energy expenditure. Energy expenditure in activity is the most variable component with respect to total energy requirements during lactation (Dewey 1997). In theory, increased energy expenditure in exercise can result in rapid weight loss; thus it is useful to examine the effects of exercise during lactation.

Cross-sectional data collected by Lovelady et al. (1990) confirm that vigorous exercise can greatly increase total energy expenditure in lactating women: in a study comparing eight sedentary and eight highly trained, exercising women who were exclusively breast-feeding infants aged 9–24 wk, average total energy expenditure measured by the factorial method (not including milk production) was about 3 MJ/d (720 kcal/d) higher in the latter group (11 vs. 8 MJ/d). The exercise group spent an average of 88 min/d in exercise, had a much higher aerobic capacity and were significantly leaner than the sedentary women. Milk volume was slightly though not significantly higher in the exercise group (839 vs. 776 g/d) despite their higher energy expenditure. However, the energy “deficit” of the two groups did not differ significantly because energy intake was higher in the exercising women than in those who were sedentary. Although this study suggested that vigorous exercise does not adversely affect lactation, it is important to remember that the groups were self-selected. The women in the exercise group may have been unusual in their ability to combine intensive exercise with successful breast-feeding.

The same group of investigators subsequently completed a randomized intervention study to evaluate the effects of a 12-wk exercise program on milk volume and composition of previously sedentary lactating women (Dewey et al. 1994). Women who were exclusively breast-feeding at 6 wk postpartum were assigned to either an exercise group or a control group. The former participated in aerobic exercise for 45 min/d, 5 d/wk during the intervention, whereas the latter did not.
exercise more than once per week during the same interval. Energy expenditure in exercise was about 1.67 MJ/d (400 kcal/d) in the exercise group. There was a significantly greater increase in aerobic capacity in the exercise group compared with controls, and this had favorable effects on insulin response to a meal and HDL cholesterol concentrations (Loveland et al. 1995). However, despite the increase in energy expenditure in the exercise group, there was no significant difference in the rate of weight loss or change in body composition between groups because the exercising women increased their energy intake during the intervention. There were no significant differences between groups in milk volume or composition, infant weight gain or plasma prolactin concentrations. The authors concluded that breast-feeding women can safely begin an exercise program without jeopardizing lactation.

EFFECTS OF COMBINED CALORIC RESTRICTION AND EXERCISE DURING LACTATION

The results of the last-mentioned study made it clear that exercise alone does not necessarily result in more rapid weight loss during the postpartum period, although it does improve the health and fitness of the women. Weight loss is usually best achieved through a combination of diet and exercise. To evaluate the effect of this combination on lactation performance, McCrory et al. (1997) designed a randomized intervention study with the following three groups: 1) control; 2) caloric restriction (to 65% of energy needs), with no change in exercise; and 3) combined caloric restriction and increased exercise, with intake estimated at 65% of energy needs. To be eligible for the study, all subjects had to be exercising at least 3 times per week initially, in order to avoid injuries if they were assigned to the diet + increased exercise group. Data were collected at base line (12 ± 4 wk postpartum) and during the 11-d intervention period. For the diet and diet + exercise groups, all of the food to be consumed during the intervention period was provided to the mothers. The diet + exercise group exercised for 60–90 min/d during 9 of the 11 d of intervention.

Of the 69 women who entered the intervention, only one dropped out of the study. The average percentage of body fat at base line was 32–33% in all three groups. Weight loss during the intervention period differed significantly among groups, averaging 1.9 kg in the diet group and 1.7 kg in the diet + exercise group compared with only 0.2 kg in the control group. In the diet + exercise group, all of the weight lost was fat mass, whereas in the diet group, about a third of the weight loss was from fat-free mass.

There were no significant differences among groups in the change in milk volume, milk energy output, nursing frequency or infant weight gain during the intervention period. However, there was a significant interaction between treatment group and initial percentage of body fat: in the diet group, but not the diet + exercise or control groups, leaner women were more likely to experience a decrease in milk energy output than fatter women. Nonetheless, only three women in the diet group experienced a decrease in milk energy output > 50 kcal/d.

Plasma prolactin response to nursing was evaluated in all subjects. Controlling for average nursing duration, parity and prolactin concentration at base line, the peak prolactin response to nursing was significantly higher in the diet group but not the diet + exercise or control groups. Leaner women were more likely to experience a decrease in milk energy output than fatter women. Nonetheless, only three women in the diet group experienced a decrease in milk energy output > 50 kcal/d.

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The results of this study suggest that, when dietary intake is controlled, a high level of aerobic exercise enhances body fat mobilization during lactation, thereby protecting milk energy output in the face of a relatively high energy deficit. In the diet group, the lack of any main effect of caloric restriction on milk energy output may be related to increased prolactin levels during the intervention, which also function to promote mobilization of fatty acids from adipose tissue or from the diet for milk synthesis. Previous studies of undernourished women have demonstrated that prolactin levels are inversely related to the level of energetic "stress" (Lunn et al. 1984). This relationship may explain why lactation is relatively well "buffered" against the effects of moderately negative energy balance.
CONCLUSIONS

Taken together, the results of the above studies suggest that, for women who are not underweight initially, lactation is not adversely affected by moderate rates of weight loss achieved by either caloric restriction or exercise. The study by McCrory et al. (1997) further demonstrates that a short period of more rapid weight loss is not harmful to lactation, and that including exercise in a weight loss program is important for maintaining lean body mass. It is unknown, however, whether there are risks associated with longer periods of rapid weight loss.

Current evidence supports the theoretical model proposed by Brown and Dewey (1992) to explain the relationship between maternal energy balance and breast milk energy output (Fig. 1). That model postulates that, for women with adequate energy reserves, milk energy output will be maintained within the normal range even if they are losing weight. For thin women, i.e., those with low energy reserves, it is hypothesized that milk energy output will be in the normal range as long as they are in neutral or positive energy balance. It is only when such women are in negative energy balance that the model predicts a decrease in milk energy output. Further research is indicated to identify the level of maternal energy reserves required to buffer lactation against energetic stress, and the threshold energy deficit below which adverse effects might be observed.

LITERATURE CITED


